TOWARD A VIBRANT, PROSPEROUS AND SUSTAINABLE FRESNO COUNTY:

Vulnerability and Adaptation in the Midst of Rapid Change

A White Paper from the California Energy Commission's California Climate Change Center

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ABSTRACT

Fresno County is located centrally within the State of California. The central portion of the county makes up part of the state's breadbasket, the San Joaquin Valley, known for its vast agricultural productivity, whereas the Sierra Nevada Mountains make up the eastern portion of the county providing water from snowmelt and varied opportunities for recreation. Fresno County recently began making a significant investment in its economic vitality and the well-being and quality of life of its residents through the San Joaquin Valley Blueprint. Aside the growing pressures and challenges that accompany further population growth and development, external pressures will also impinge on the county. Climate change – one of these important additional pressures – will impact Fresno in a variety of ways, some potentially severe, with direct impacts on its people, its all-important agricultural sector (and related economic activity), its supporting infrastructure and services, as well as the natural environment on which much of the county's economy, rural character, and quality of life directly depend. This report details current vulnerabilities to weather- and climate-related changes and extreme events in Fresno, and explores how climate change may exacerbate or change them in the decades ahead. The report draws on publicly available reports, plans, and data repositories available from local (municipal and county), state, federal and non-governmental sources as well as on peer-reviewed research papers. For the social vulnerability assessment, original research was conducted to assess differential vulnerabilities among San Luis Obispo's population. Other assessments of vulnerability rest on the critical assessment of current conditions as ascertained from the existing information.

This report provides a review of the region's projected climate change and existing demographics and economic industries and infrastructure. Among the most critical additional stresses from climate warming are increased average seasonal temperatures; longer, more intense heat waves; changes in rainfall patterns and water availability (via Sierra snowmelt); and increases in wildfires. The changes could translate into major damage in terms of public and environmental health, and Fresno's economy, e.g., the production of nut and fruit crops. From the social vulnerability analysis conducted, a clear picture of differential social and economic vulnerabilities emerges characterized above all by the enormous dependence of the county's economy and population on the highly climate-sensitive agricultural sector. These growing issues, while challenging, can be surmounted with timely and adequate planning and preparation. City and county governments, as well as private and civic sector actors, can integrate adaptation into their ongoing efforts to implement already existing plans, such as the Valley Blueprint, Fresno Green and other local and regional measures. Many of these social, economic, institutional, educational, and infrastructure measures can be implemented on regular maintenance, upgrading, planning, and budgeting cycles, and bring benefits to the county's residents, particularly its disadvantaged groups, its quality of life and environment, its fiscal situation and its economy overall. Thus, developing adaptation plans and implement agreed-upon measures is directly in support of Fresno County achieving its vision of a vibrant, prosperous and sustainable future.

Keywords: regional climate studies, Fresno, climate vulnerability

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Section 1: Introduction

1.1 Fresno County's Vision of a Vibrant, Prosperous and Sustainable Future

A Vision for Fresno in 2050

"Fresno County is home to unique cities, communities and a diverse population, a healthy, sustainable environment, a vibrant economy built on competitive strengths and world class education and a system of high capacity multi-modal transportation corridors, where cultural and community stewardship is an guiding value, allowing all people to enjoy fundamental rights as members of a free society, and where the community takes ownership of problems and their solutions."

(Source: Valley Blueprint)

In early 2006 the eight Councils of Governments in the San Joaquin Valley began developing a common vision for the Valley – the San Joaquin Valley Regional Blueprint.[1] Fresno County – the largest of the eight-county consortium – is participating in this effort through its own, yet coordinated planning and implementation of Blueprint-guided land use and transportation decisions. With financial support from state and federal governments, Fresno thus embarked on a significant investment in its economic vitality and the well-being and quality of life of its residents (see A Vision for Fresno in 2050 above).

Fresno's Blueprint is intended to help urban areas in the county to better deal with existing and expected future growth-related challenges to public resources, housing, mobility, the health of Fresno's population, its air quality and environment. While its emphasis is on economic and demographic growth and changes, the Blueprint recognizes that the environment will be under growing pressure from development, and it, too, is changing, driven particularly through changes in the global climate.

In 2008, experts at the California State University in Fresno (CSUF) completed a study for the City of Fresno to assess what the specific additional challenges may be arising from climate change, and how the City might address them. The resulting study laid out potential climate-related threats to the city and county and suggested a variety of actions local governments, in collaboration with the private sector, could take to reduce local sources of emissions of heat-trapping gases and related air pollutants.[2] It also offered a small number of actions to deal with the unavoidable impacts of climate variability and change, such as increasing heat extremes. Virtually the entire suite of proposed strategies and actions are consistent with, and in fact, integral to the County's Blueprint principles and strategies (see Appendix B for the full list of strategies).

This report was written to offer the City and County additional insights to build on the intention and momentum of the regional Blueprint and the CSUF study's recommendations. The focus here is primarily on the social, economic and demographic conditions and how they vary geographically across the county. Along with the pressures of growth, they shape how different communities, segments of the population, economic sectors, and the underlying infrastructure and community services differ in their susceptibility to change, in their vulnerability to climate-related risks (Figure 1). Regardless of the exact magnitude or causes of

future changes in the climate, Fresno can efficiently focus and further enhance its efforts to plan ahead for a vibrant, prosperous, and sustainable future with a fuller understanding of these differential vulnerabilities. The purpose of this report, then, is to provide insights and information to augment existing efforts, to refine current strategies, and offer additional options to meet the challenges of the future and ensure the realization of Fresno's vision.

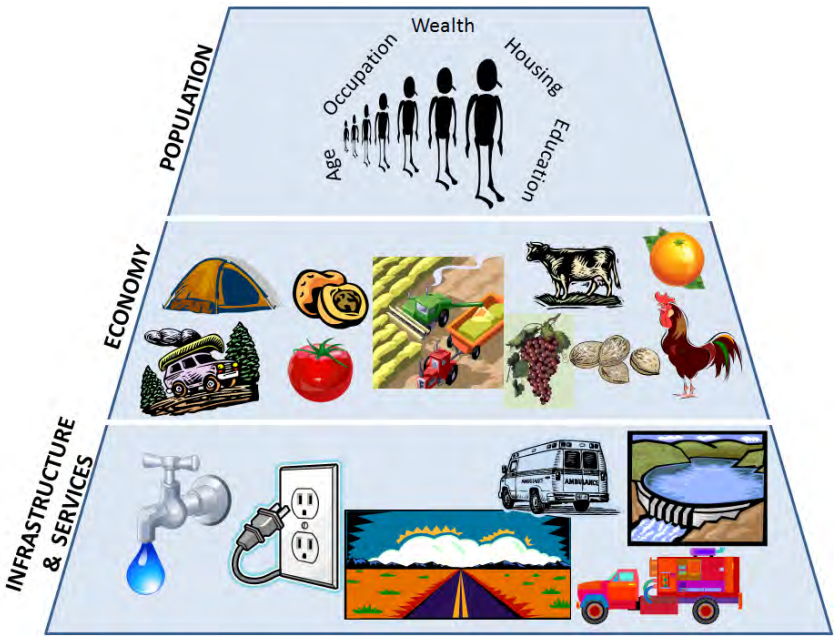

Figure 1: Main elements of the report: Population, economic sectors, infrastructure and supporting services

1.2 Focus & Organization of the Report

The specific focus of this report is to provide background information about Fresno County and the apparent vulnerabilities of social systems (populations, economic sectors, critical infrastructure, and community services) to the potential impacts from climate change. The report served as a basis for a stakeholder workshop in the county, at which participants refined previously identified strategies and further developed additional ideas for how to reduce these vulnerabilities to help realize the 2050 vision for a vibrant, prosperous, socially just, and environmentally sustainable region. Any steps the County and City of Fresno take in this regard will serve to prepare for, and adapt to the unavoidable impacts of climate change, and thus is consistent with the recently released statewide adaptation strategy.[3]

A second report and workshop, organized by the National Center for Conservation Science and Policy (NCCSP) (now The Geos Institute), focused on potential climate change impacts and adaptation options for the county's vital natural ecosystems and conservation areas.[4] A functional and healthy natural environment is a critical foundation for Fresno's economy, quality of life, and the health and well-being of its residents. Thus, the current report views the other one as a critical foundation and complement to the focus here on social systems.

To fully understand what climate change will actually mean for local communities, science-based projections of potential changes in the physical climate (given selected greenhouse gas emissions scenarios) are essential, but not enough. What is equally necessary to complement these scenarios of future climate (i.e., changes in temperature, rainfall, extreme events such as floods and droughts, and sea-level rise) is a better understanding of the current (and future) conditions of the potentially affected natural and social systems. While climate change projections offer a glimpse of the physical hazards that may arise from global warming, or that a community may be exposed to, an assessment of the current condition of affected systems provides insights about the community's "on-the-ground vulnerabilities." In this report, we focus primarily, though not exclusively, on these on-the ground vulnerabilities. They will help identify adaptation actions that could be considered no- or low regrets options, not because they are necessarily no- or low-cost or easily implemented, but because they can yield benefits to the environment, economy and to people regardless of precisely how climate change will unfold. In no or low regrets options, the risk of failing under current or changed future conditions is low.

Thus, in this report we will offer a broader perspective than just climate-scenario dependent projections of climate change impacts on the county's people and economy. Instead, we will summarize what is known about these potential impacts, but primarily examine available information about demographics (race, wealth, education levels, special populations, etc.), locally important economic sectors (agriculture, tourism, services, etc.), important infrastructure (roads and energy) and community services (transportation, emergency management and response, etc.), and the necessary natural resources (water, healthy ecosystems and the goods and services they provide) to support the county's economy and residents to better understand how the region and communities within the County are vulnerable to climate change.

The report draws on publicly available reports, plans, and data repositories available from local (municipal and county), state, and federal sources as well as on and peer-reviewed research papers. For the social vulnerability assessment, original research was conducted to assess differential vulnerabilities among San Luis Obispo's population. Other assessments of vulnerability rest on the critical assessment of current conditions as ascertained from the existing information.

To present such a diversity of background information, this report is organized as follows. First, we will introduce a few concepts that are central to thinking about vulnerability and developing adaptation strategies. Key concepts include: vulnerability, exposure, sensitivity, adaptive capacity, coping, adaptation, and resilience. Second, we will present a summary of modeled climate change projections (biophysical impacts – temperature, rainfall, wildfire, etc.) for the region to remind readers of the potential physical risks the county may be exposed to. At the time of the writing on this report (prior to a workshop with stakeholders in the county), the available information for San Luis Obispo was restricted to the report prepared by Koopman et al. Since then, additional down-scaled climate change projections have become available and can be found at the state's interactive climate information portal, cal-adapt.[5] Finally, the core of the report will present information about the population, economic sectors, water, and infrastructure and supporting services (Figure 1). This information will be related to the concepts introduced earlier to illustrate how certain demographic, socio-economic and other factors make Fresno's residents and economic activities more or less vulnerable to climate

change. They will also indicate what capacities the county already has to draw on and could further leverage to begin the process of adaptation.

1.3 What is Vulnerability? What is Adaptation?

The effects of climate change in Fresno County, the State of California and around the world will differ widely. The changes will produce very different local impacts in part because of the regional differences in the nature of expected climate change (whether it is higher temperatures, rainfall changes, or patterns of extreme events) and because of the regionally varying conditions of the affected systems. Together, the physical changes in climate, and the condition of the natural and human systems with which climate interacts, will determine the potential impacts, while actions to reduce the causes of global climate change and actions to minimize local impacts will determine the ultimate impacts.

For the purposes of this report, we employ the terminology used in the State of California's first Climate Adaptation Strategy.[6] We first distinguish climate change impacts from vulnerabilities. A ***climate change impact*** is an effect of climate change on the structure or function of a system. Potential impacts are those that may occur without considering adaptation. By contrast, ***vulnerability*** – in the most general sense – describes a system's susceptibility to harm or change. Vulnerability is the combined result of exposure, sensitivity, and adaptive or response capacity and as such a function of the character, magnitude, and rate of climate change to which a system is exposed, as well as of non-climatic (social and environmental) characteristics of the system, which determine its sensitivity and its ability to respond to change.

First, ***exposure*** is the nature and degree to which a system experiences a stress or hazard.[7] Examples of stresses that are familiar to some or all parts of the county include heat waves, water shortages, wildfires, flooding from runoff and storms, dam failure, and large scale power outages during heat waves and other high-demand periods. Many of these may be exacerbated by climate change. The levels of exposure from a stressor often are not distributed evenly across a geographic space or across populations (e.g., inland areas will experience extreme heat more than coastal areas; areas in or near flood-prone areas will be at greater risk of experiencing floods than those in elevated areas; individuals working in office buildings will experience the same heat wave less than outdoor workers). It is also important to note that climatic hazards can be one-time extreme events or slow creeping problems that are more chronic in nature, which – if not addressed – can eventually lead to a very challenging situation (e.g., an acute heat wave versus chronic water shortage). Thus, how exposure is distributed across space and populations, and the nature of the climate perturbation, are important for understanding local level vulnerability. The section below on climate change projections summarizes the best available science at present on what climate changes and perturbations the county may be exposed to in the future.

The second dimension of vulnerability is ***sensitivity***, which refers to the degree to which the system is impacted by a given stressor, change or disturbance.[8] The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors).[9] The sensitivity of a system is not just the result of climate-stresses, however. It is also influenced by unrelated non-climatic stresses. For example, the elderly and frail are generally

found to be more sensitive to extreme heat than healthy adults. People already under significant amounts of stress for health, economic, or psychosocial reasons may be more susceptible to additional climate-related health stresses.

The third dimension of vulnerability is ***adaptive (or response) capacity***. We use this short-hand here to include the ability to cope with extreme events, to make adaptive changes, or to transform more deeply, including the ability to moderate potential damages (negative consequences) and to take advantage of opportunities (beneficial consequences). While there are a number of ways to measure and evaluate adaptive capacity, this concept relates to the degree to which the system can adapt in order to deal with a stressors or change. Adaptive capacity can be assessed on any level of organization, from the individual to the national or international level. Here we focus on the individual and community levels (i.e., a municipality, special population or economic sector). The factors that tend to increase adaptive capacity include economic resources, highly functional institutions, adequate infrastructure, availability of technological options and capacities, sufficient information and high levels of education and skill among decision-makers and stakeholders, significant social capital among stakeholders, and equity in the access to these resources and capacities. (These factors are explicit targets for improvement in the Valley Blueprint.) In this report we focus extensively on these characteristics of the county's population and economic sectors (Figure 2).[10]

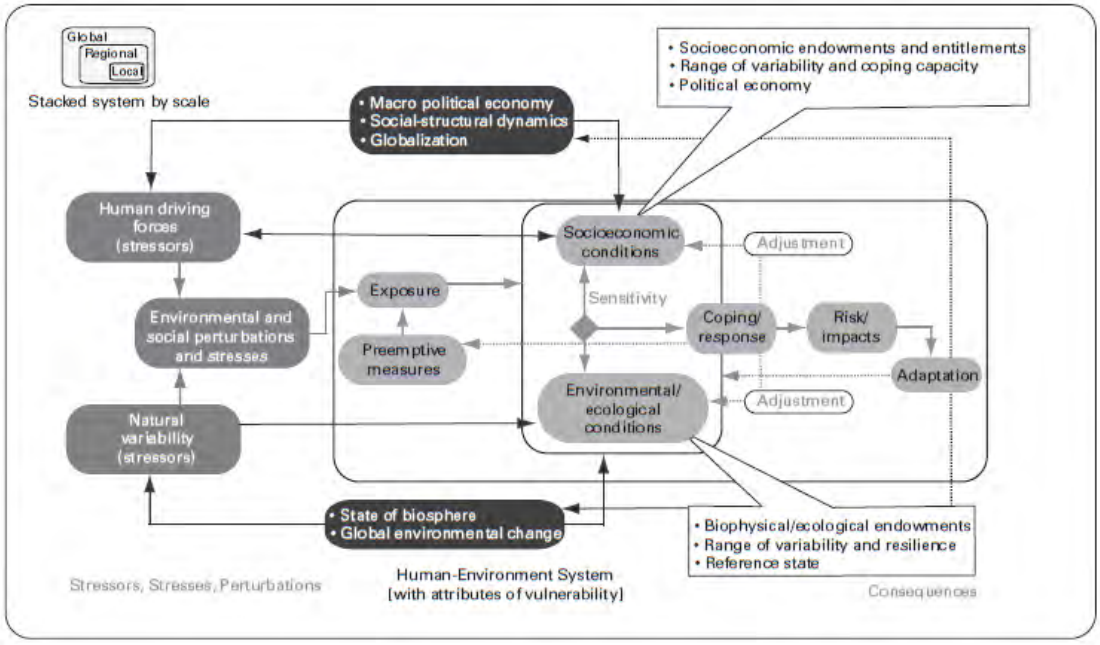

Figure 2: The three core components of vulnerability (exposure, sensitivity and the capacity to cope and adapt) combine to result in actual consequences from a hazard (e.g., a climate-driven extreme event or other perturbation or stressor). Adaptation and coping strategies can reduce these impacts by reducing exposure and/or sensitivity of a system to the climate change or by increasing its coping and adaptive capacity, any of which could increase the system's resilience. The diagram illustrates the dynamic relationships between these concepts and how to assess vulnerability for one point in time in order to help identify useful adaptation strategies.

(Source: Kasperson, Kasperson and Turner 2009)[11]

Adaptation is frequently defined as any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities.[12] Because some impacts of climate change are already beginning to manifest, both sets of actions are now considered equally necessary and complementary to each other (see also the Appendix B). Mitigation limits the pace and ultimate degree of climate change, thus making it possible for natural and social systems to adapt, while adaptation addresses the consequences of change that could not be avoided. For individuals familiar with disaster preparedness and management, "mitigating" potential impacts from disasters are among the actions one might take to prepare for and adapt to climate change. To avoid unnecessary confusion, in this report, we will refer to adaptation as all those actions one might make to prepare for and deal with the impacts of climate change.

Finally, ***resilience*** is the ability of a system to absorb some amount of change, including shocks from extreme events, bounce back and recover from them, and, if necessary, transform itself in order to continue to be able to function and provide essential services and amenities that it has evolved or been designed to provide.[13] In light of the potential risks from climate change, resilience has become a highly desirable outcome of adaptation.[14] If adaptive actions can help a system be better prepared, bounce back faster and better from an extreme event, learn from such events, deal relatively easily with changing conditions, adjust over time, and continue to provide desirable goods and services, then adaptation may be considered successful.

1.4 Geography and Climate Change Projections for Fresno County

1.4.1 Topography, Land Use, and Current Climate Conditions

Fresno County is located in the center of California's San Joaquin Valley, which forms – together with the Sacramento Valley – the Great Central Valley (Figure 3). Fresno is bordered by Madera and Merced Counties to the north, Tulare and Kings Counties to the south, San Benito and Monterey Counties to the west and Inyo and Mono Counties to the east. The county has a land area of nearly 6,000 square miles and an average population density of about 75 persons per square mile (compared to the State's average of over 217 people per square mile). At the same time, it is the county with the largest population of the eight Central Valley counties.[15] The topography of the county varies between the eastern foothills with the flat valley floor (of the Central Valley) in the middle, and the Sierra Nevada Mountains on the eastern portion of the county (reaching up to 14,000 feet). The valley region makes up approximately 45% of the county land with the remaining 55% is mountainous terrain. The two major rivers in the county are Kings and San Joaquin Rivers, both of which originate in the Sierra Nevada Mountains.[16]

Figure 3: Fresno County is located in the center of the San Joaquin Valley, which – together with the Sacramento Valley – forms the Great Central Valley. [17]

The county's physical topography, ecosystems, and land use are largely divided into three regions so that there is a clear distinction between the eastern portion, the valley floor, and the very western portion (foothills of the coastal range) of the county. The eastern portion is primarily rural and mountainous, as part of the Sierra Nevada Mountain Range, much of which is public land owned by the US Forest and Park Service (including Sequoia National Park and the Sierra National Forest) (Figure 4). About 40 percent of the entire county (mostly in foothill and mountain areas) is publicly owned, predominantly by the federal government.[18] The valley region (about 50 percent of the total county land area) is dominated by rich and productive farmland and agriculture-associated industries.[19]

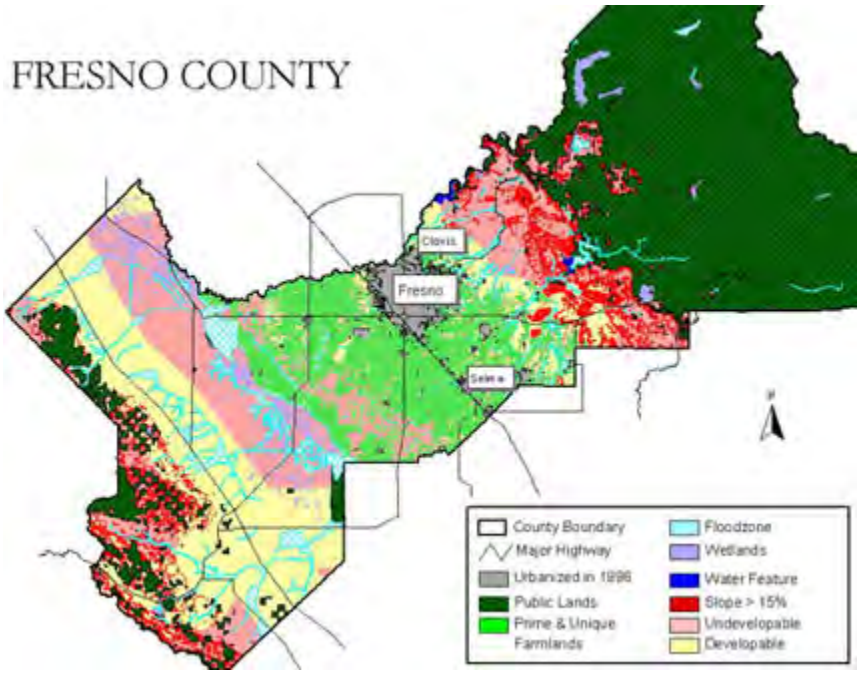

Figure 4: Land use map of Fresno County. While most of the eastern part of the county is public land, central and western portions are developed or farmlands

(Source: Desert Research Institute)[20]

The current climate of Fresno County varies between its three regions. The low-elevation valley, where most of the agricultural industry is located, has a Mediterranean climate with hot and dry summers and moderate, humid winters with moderate precipitation with an average historic precipitation of 10.9 inches per year.[21] The coastal foothills on the western side of the county have moderate to hot summers, while the higher-elevation Sierra Nevada in the western region of the county are relatively cool during the summer. Winters in the western and valley regions are relatively short and have light rain (the months from October to April historically [1948 to 2008] had an average of 10.21 inches of rainfall[22]), while the winters of the Sierra Nevada include rain and often extensive snow, depending on the altitude.[23] Snowfall in the Sierras serves as a critical water resource not just for the county, but for the entire state.

1.4.2 Summary of Future Climate Change Projections

The Institute of Climate Change, Oceans and Atmosphere (ICOA) at the California State University-Fresno in 2008 produced a report synthesizing the scientific research on climate change science and potential impacts on the region.[24] Since then, several additional studies conducted for the State of California – as part of the state's periodic impacts assessments – and an independent study conducted by the National Center for Conservation Science and Policy[25] provide additional indications of the potential climate changes that Fresno may expect in the future. Here, we only summarize the key findings of these studies. According to these studies, assuming business-as-usual scenario of heat-trapping emissions, Fresno County could experience the following changes[26]:

- an increase in average temperature of 2-6.0 °F in summers by 2050, and 5.2-11.0 °F by 2100, and an 2.0-4.1 °F increase in winters by 2050 and 3.7-7.9° F in winter temperatures by 2100 (Figure 5)
- a 22-30% increase in the number of days of extreme heat (over 104 °F) by 2050, and a 36-61% increase over historical averages by 2100 (Fresno experiences 92 such days /year currently [i.e., over the standard historical period of 1961 and 1990])[27,28]
- a decrease in the availability of state water from snow melt due to the overall slight decline in precipitation, and a greater proportion of precipitation falling as rain than as snow
- runoff from snowmelt will also occur earlier in the spring, extending the period where water availability is more limited; reduced snowmelt and runoff also affects hydroelectric power production[29,30]
- an increasing risk of dry years and droughts as a result of higher temperatures, higher evaporation and, eventually, a decline in precipitation
- increasing floods due to higher number of extreme rainfall events, especially if combined with projected warmer winters and spring temperatures, when snowmelt and winter/spring rains coincide
- an increase of the total area burned annually by wildfires is projected to increase between 300-400% in the Fresno area by the end of the century[31]
- a possible increase in "bad air" days (warmer air increases the formation of ozone, a key component of smog)

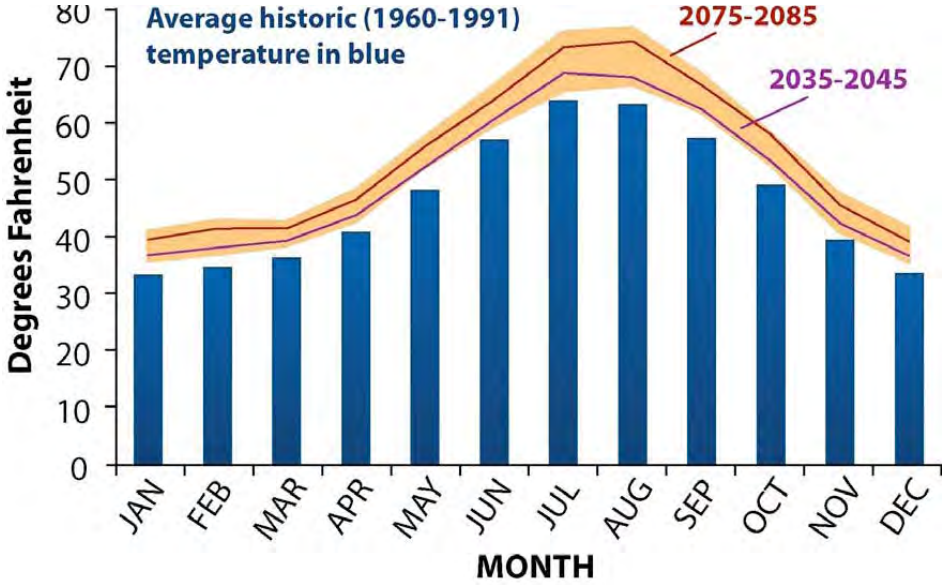

Figure 5: Projections of temperature increase in Fresno County

(Source: Koopman et al., 2010)[32]

Table 1: Projected increase in average temperature in the upper and lower Fresno County regions, from three global climate models. Future projected temperature is shown as change in degree Fahrenheit, as compared to historic averages (1961-1990).

	Historic		2035-45		2075-85	
Season	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
Annual	46.4° F	62.3° F	+2.5-4.8° F	+2.3-4.3° F	+5.2-8.9° F	+4.7-8.2° F
Summer	61.3° F	78.0° F	+2.2-6.0° F	+2.0-5.4° F	+5.8-11.0° F	+5.2-10.0° F
Winter	33.9° F	47.0° F	+2.2-4.1° F	+2.0-3.8° F	+4.1-7.9° F	+3.7-7.4° F

(Source: Koopman et al. 2010)

Across Fresno County, temperatures are projected to increase. When dividing the county into upper and lower regions (i.e., the east and west side, respectively), by the middle of the century the upper region is projected to increase annual average temperatures by 2.5-4.3 °F and then up to nearly 9 °F by the end of the century (Figure 5). In the lower region, where the majority of the population and industry are located, annual average temperatures are projected to increase by 2.3-4.3 °F by midcentury and up to 6 °F during the summers. By late century, annual average temperatures are projected to increase by 4.7 to 8.2 °F and summer averages 11 °F (Figure 5).

For the urban center of Fresno, climate models project an increase in the number of days that exceed the local heat threshold of 104 °F.[33] Depending on the greenhouse gas emissions scenario and model used, Fresno is projected to see an increase in the number of extreme heat days from 92 historically (1961-1990) to 113 to 120 days by the year 2035.[34] By the end of the century, there

could be as many as 126-149 extreme heat days (i.e. 4-5 months per year) unless climate change is curbed through effective global efforts.[35]

In addition to the direct impacts on Fresno's climate, it is important for the county to be cognizant of the impacts climate change induces beyond its borders. Water supplies so crucial to the county's agricultural industry and its residents come from sources largely beyond county borders. The quantity and timing of water availability and supply upon which Fresno depends could be substantially affected by climate change. Much of the agricultural water is supplied by Kings River from the southern Sierra Nevada Mountains to the east and from the aquaducts from northern California, which originates from snowmelt of the northern Sierra Nevada Mountains. The best available studies for California show a decrease in annual reservoir inflow (from Sierra snowmelt and rain runoff) by 14-23% by mid-century and a total decrease of up to 43% by the end of the century.[36] The groundwater basins that supply the majority of water to urban and rural residences, as well as some farming operations, rely on annual recharge from water that also flows down from the Sierra Mountains.[37]

While sea-level rise will not affect Fresno County directly, as with rain- and snowfall, it is important for Fresno County to be aware of what happens beyond its borders. Fresno, along with all the other regions in California supplied by Pacific Gas & Electric (PG&E), receives a significant portion of its energy supply from the Diablo Canyon power plant located near the coast. That location is exposed to the impacts of sea-level rise (current best estimates range from 12-17 inches by 2050, and 23-55 inches by 2100)[38], including flooding and coastal erosion. Plant managers will need to ensure that as sea level rises and thus the base flood elevation rises, the plant is still protected and can function without interruption. In addition, PG&E relies on in-state hydropower, the production of which is also projected to decrease in the late summer and early falls months as snow melts earlier in the year.[39]

While the hydrologic and water supply conditions, precipitation, and temperatures are already affected by climate change, the severity of future climate change impacts are not set in stone for Fresno. The projections based on a future of further increases in global greenhouse gas emissions shows a future with more extreme heat waves, temperature and seasonal changes, and water shortages when compared with a future with much reduced global emissions. If Fresno, California and the global community follow a path toward significantly reduced emissions, the future would hold significantly fewer extreme heat days[40], and much less reduction in snowfall and thus inflow into reservoirs, than if the world chose a higher-emissions pathway.[41]

As these projections indicate, uncertainties remain as to the exact impacts on Fresno County. Among the most important uncertainties is how the global community responds in limiting future global warming. Yet even with significant efforts to reduce emissions, the county is at risk of experiencing a variety of impacts. With adequate planning, preparation and adaptive measures, which are entirely commensurate with the Valley Blueprint, those impacts can be minimized and Fresno will be in a better position to take advantage of potential opportunities.

Section 2: Communities and Populations of Fresno County

2.1 Differential Vulnerability among Populations

Fresno County is a predominantly rural county with the majority of the population centered in a relatively small area around the City of Fresno. Its population over the past few years has been growing at a moderate rate, and is expected to continue to do so, leading to a projected doubling of the population by 2050. Most of this growth will result from reproduction by the local population and immigration to the area.[42] The profile of the existing population, the amount of growth, and the type of incoming new residents are important to consider with respect to their vulnerability to climate change.

Certain segments of the population commonly have higher than average sensitivity and exposure to climate variability and disasters. For example, elderly and infants tend to be physically more affected by extreme heat and extended heat periods (especially at night). Similarly, people working outdoors (agricultural, construction, and other kinds of outdoor workers) are more exposed to high temperatures and heat waves than indoor workers. Residents living in floodplains are more exposed to storm-related flooding than those living outside of flood zones, whereas forested areas along the foothills of the coastal or Sierra Nevada Mountains are more susceptible to landslides and wildfires.

In this section we show how different segments of the population deemed more vulnerable to some climate change impacts are spatially distributed throughout the county. We also present the distribution of those population segments that tend to have lower response capacity than the average population. We begin this section by presenting some basic statistics about the general makeup of the county population to provide essential background, but then focus our discussion on the implications for various public health risks (especially heat, air pollution, and flooding risks).

2.2 Population Overview

According to the U.S. Census, Fresno County had an estimated population of 915,267 in 2009, a rise of nearly 15% since 2000, which is lower than the rise of California's population statewide.[43] However, the Central Valley as a whole is expected to have major growth, especially in the cities, by the middle of the century.[44] The largest municipality is the City of Fresno with 495,913 people in 2009 (Figure 6), holding over half of the county's population, followed by Clovis (93,246 in 2009[45]), and thirteen smaller cities (including Reedley, Sanger, Selma, Coalinga, Parlier, Kerman and others). Nearly 20% of the county's population lives in unincorporated areas (with government affairs overseen by the County).[46]

Populations are projected to increase in the county substantially over the next 30 years. By 2025 Fresno County of Governments (COG) reports that the population is projected to be nearly 1.3 million, up from approximately 915,000 people in 2009, and is expected to continue to grow (up to 2.5 million by 2100[47]), especially in Fresno and other urban centers.[48,49]

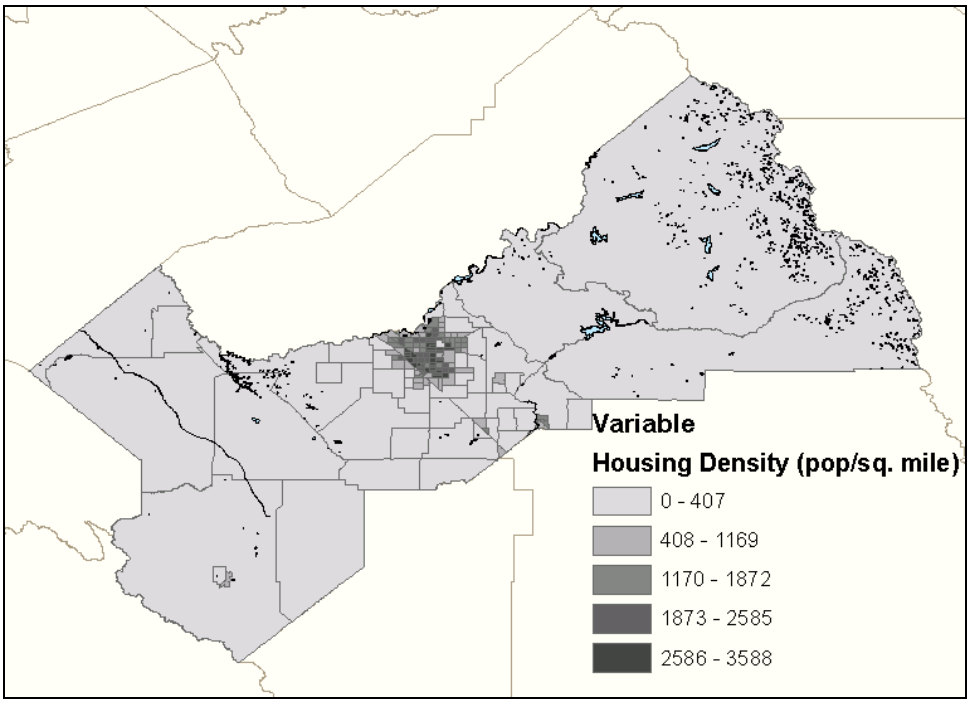

Figure 6: Housing density per square mile

(Source: Census 2000)

The county's population includes slightly more children under 5 years, more youth under 18, and a lower proportion of people over 65 than the state average. However, the population over 65 years is expected to more than double by 2040 (to over 1 million older adults).[50] In terms of racial diversity, in 2008 the county population was over 48% Hispanic/Latino, 35% white (non-Hispanic), 8.5% Asian, and 4.9% African Americans (Figure 7).[51]

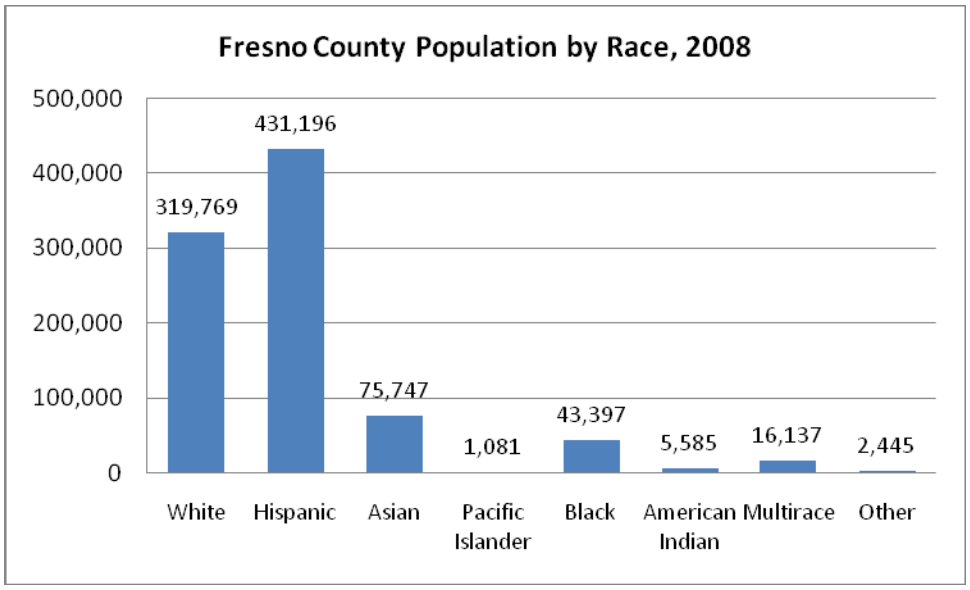

Figure 7: Racial Diversity of Fresno County, based on 2008 Census Data

(Source: US Census American Community Survey 2006-2008)

While homeownership rates in 2000 were very similar to the state average (nearly 57%), the recent economic downturn has led to a high rate of foreclosures in the county (1 out of 170 houses is in foreclosure, as of June 2010).[52] The Census 2000 data show that median household and per capita income are significantly lower than statewide figures, and poverty levels are 22.1%, which is significantly above the state average of 13.3%.[53] In 2000, the agricultural cities of Orange Cove (44.54%), Mendota (41.88%), Huron (39.4%), Parlier (36.02%), and San Joaquin (34.59%) ranked as the cities with the highest percent of persons living below poverty in the county.[54] Below, we examine population characteristics more specifically with its implications for vulnerability to climate change impacts on public health.

2.3 Public Health

Climate change may have a substantial impact on public health in California as a result of changing conditions (e.g., extreme heat events; changes in temperature and rainfall that decrease water supply; worsening air quality; increases in allergens and air pollutants; more wildfires; spread of insects and rodents carrying diseases; and indirect impacts via changes in food security).[55] These increasing threats to public health can increase mortality and morbidity unless actions are taken to protect the population, especially those most vulnerable.[56] California's statewide Adaptation Strategy highlights that the segments of population that will be most at risk from climate change impacts are the "elderly, infants, individuals suffering from chronic heart or lung disease, persons with mental disabilities, the socially and/or economically disadvantaged, and those who work outdoors."[57] In terms of the three components of vulnerability, different population segments demonstrate greater vulnerability to these threats than others. We highlight several important examples (Table 2), but note that in reality, the three components have to be assessed for all groups in an integrated fashion to develop a comprehensive sense of vulnerability.

Table 2: Examples of Climate-Related Environmental Changes or Extreme Events or Interacting with the Three Components of Vulnerability

Components of Vulnerability	Projected changes or events exacerbated by climate change	Population Particularly at Risk
Exposure	Floods	Floodplain residents
	Heat	Outdoor workers
	Wildfire	Residents the urban-wildland interface
	Pests and infectious disease	Individuals in crowded and poor living conditions
Sensitivity	Heat, Air pollution	Infants, populations with asthma
	Heat	Elderly
Adaptive Capacity	Heat, Floods, Infectious diseases	Socially excluded and/or economically marginalized groups (e.g., migrant workers)

2.3.1 Exposure

Floodplain Residents at Risk from Extreme Runoff and Flooding

Floods have historically been frequent in Fresno County along the banks of the county's two major rivers (Kings and San Joaquin Rivers) and a number of smaller creeks (Figure 8). Flood control is in place throughout the county to prevent flooding and damage of these waterways in the form of reservoirs, levee systems, and designated open space reserves. "Most of these systems are privately owned, maintained, and operated."[58] Therefore, while the federal and county flood control must abide by enforcement, regular monitoring (and jurisdiction) of mandatory safety standards, many private flood control efforts (i.e., the dams and levees on private property) often do not meet the government-required standards for flood protection.[59] Climate change could exacerbate flood risk in Fresno County after extreme downpours or even dam failure at reservoirs of Millerton Lake (Friant Dam), Big Dry Creek Dam, Redbank-Fancher Creek Project Dams, and Pine Flat Dam due to increased severity of runoff in the winter and early spring (see also the Dam and Levee Failure section below). The County General Plan Update records that these "four major dams could cause substantial flooding in the Fresno County in the event of a failure,"[60] of which the inundation areas are shown in Figure 10.

Figure 8: Flooding in Fresno County

(Photo: Fresno County)

Climate change is expected to lead to more extreme downpours and thus runoff, which can cause flooding along area creeks and rivers (e.g., San Joaquin and Kings Rivers), of roads, homes, and agricultural fields. If there are long-lasting rainfall periods (as is already common in the winter) the capacity of streambeds and reservoirs could be overwhelmed, increasing the risk of dam failure and flooding. People living in low-lying areas, floodplains, and downstream of the Big Creek Dam (City of Fresno) and Pineflat Dam are at particular risk (

Figure 9, Figure 10). In 2005, for example, severe weather caused street flooding that damaged 25 homes and businesses in the City of Parlier (southeast of Fresno) causing an estimated $1 million in damage (which portion of these estimated losses were insured is unclear).[61] Moreover, as snow melts sooner in the year, meltwater runoff may coincide with the rainy season (when land is already highly saturated), thus increasing the flood potential across the county.

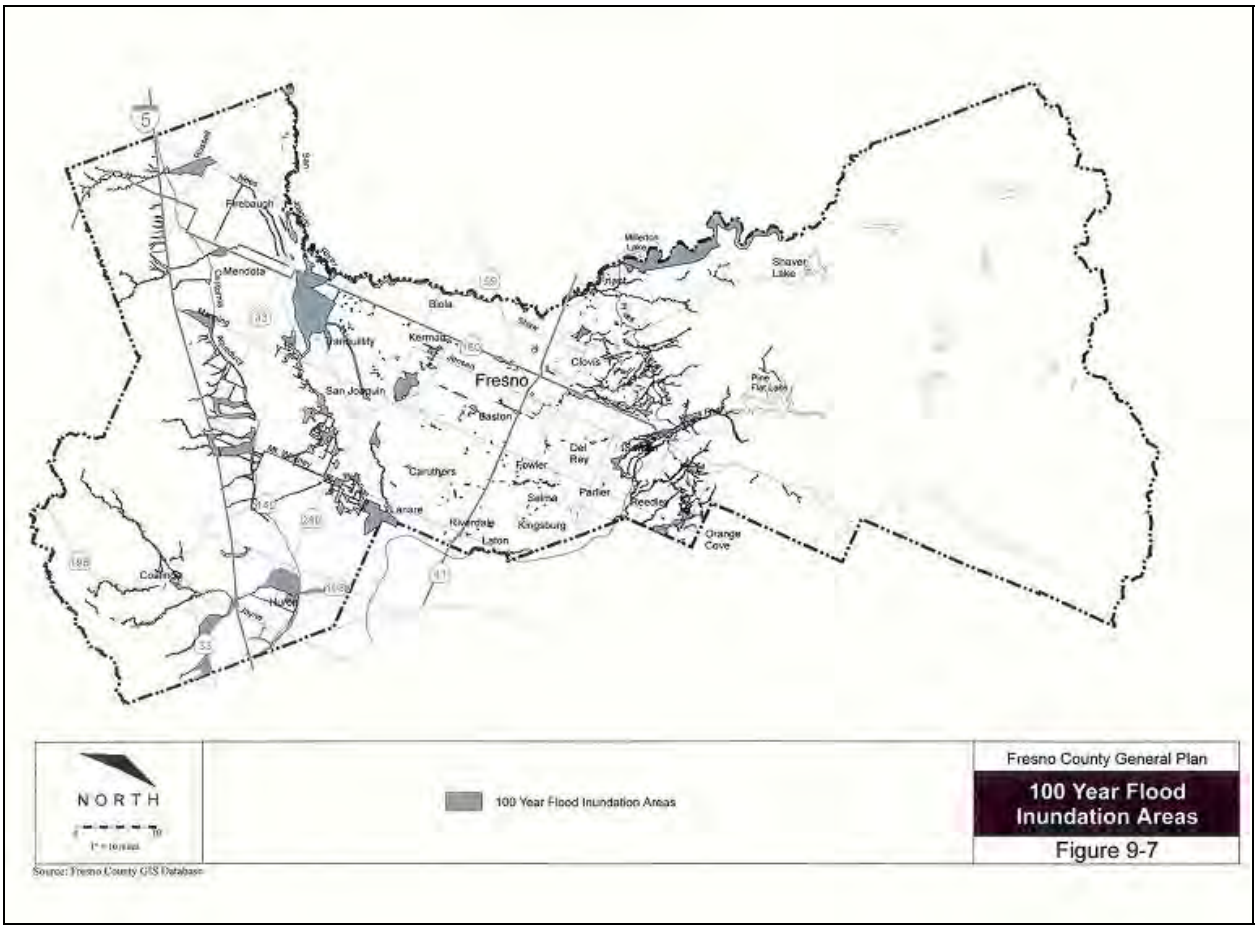

Figure 9: 100 Year Flood Inundation Areas in Fresno County as designated by FEMA

(Source: Fresno County General Plan Background Report 2000, Fig. 9-7)

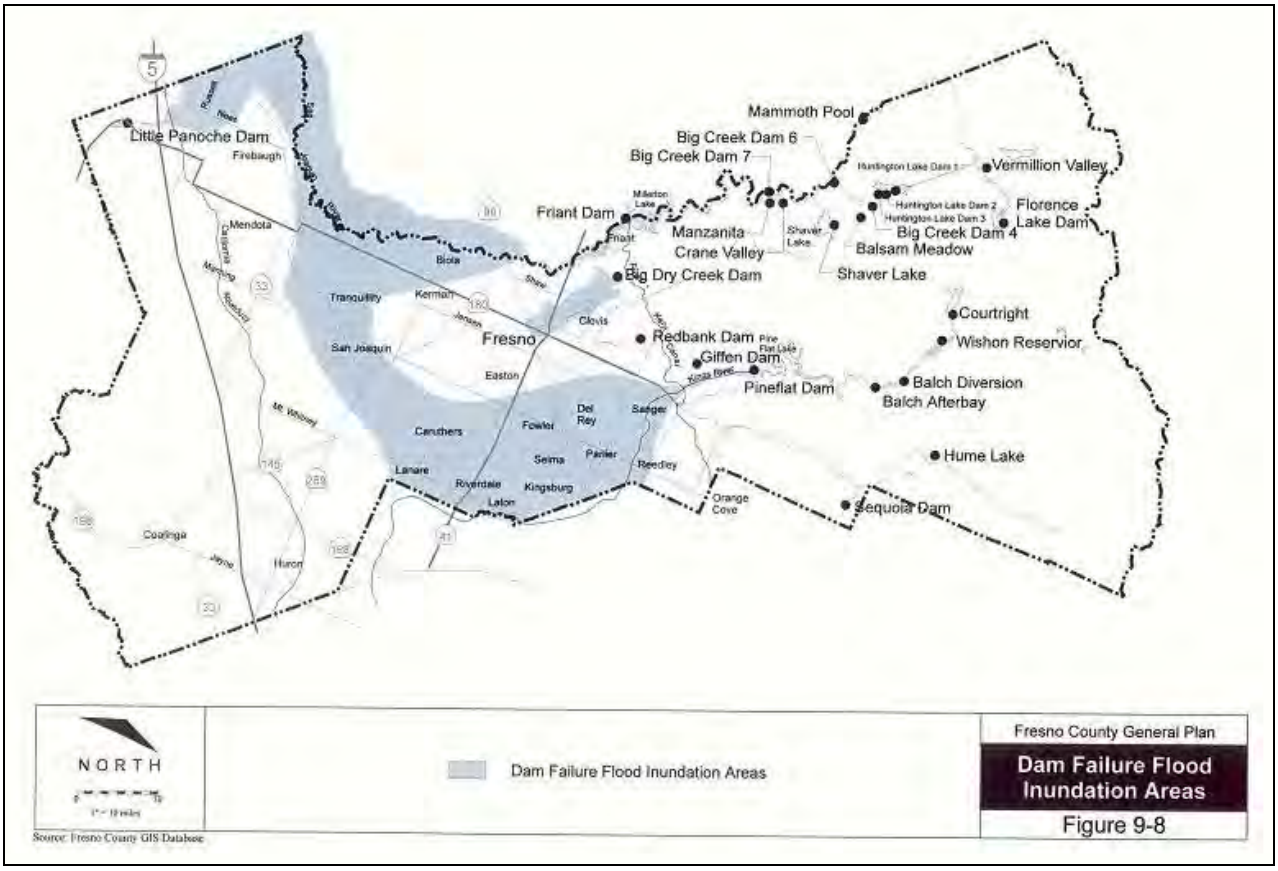

Figure 10: Dam Failure Flood Inundation Area in Fresno County

(Source: Fresno County General Plan Background Report 2000, Fig. 9-8)

Outdoor Workers Exposed to Extreme Heat and Air Pollution

People who work outside are directly exposed to outdoor conditions, and they tend to have little choice about it. Exposure to temperature extremes is of particular concern for these individuals, regardless of age, especially those working in low-elevation inland areas like the Central Valley. Examples of such populations are (migrant) agricultural field workers and gardeners for residential and commercial establishments, as well as road and building construction workers (Figure 11). Climate change-related temperature increases will put these workers even more at risk of heat exhaustion, sunstroke, dehydration, and other heat-related illnesses unless effective measures are put in place (i.e., mandated, implemented, and monitored) that allow outdoor workers to seek shade, cool off, and remain adequately hydrated.

Figure 11: Farm and other outdoor workers are particularly exposed to extreme heat.

(Photo: Holger Hobbs, Wikimedia Commons)

The Central Valley and Fresno are already familiar with these challenges. In response to the health risks of working in the high temperatures, farm workers in the Central Valley filed a lawsuit in 2009 against the State of California and its Occupational Safety and Health Standards Board (Cal/OSHA) for not providing sufficient protection for preventing heat illness.[62] The National Farm Worker Ministry reports that at least 15 farm workers have died of heat-related illness in the Central Valley between 2004 and 2008.[63] This number may be higher in reality given that deaths do not necessarily get reported with the cause. Most recently in June 2010, a farm worker died of heat illness in neighboring Kern County[64], demonstrating clearly how heat exposure is already a problem and is likely to get worse the higher summer temperatures rise.

In addition to the extreme heat, outdoor workers are also highly exposed to the region's high air pollution. This includes particulate matter from "tilling of dry soil, agricultural burning, crop harvesting and diesel-powered water pumping. Particle emissions include inorganic compounds from soil lofted by, for example, dairy operations and off-road vehicles, or organic matter from animal feed and disturbed, dried manure."[65]

2.3.2 Sensitivity

Greater Sensitivity to Extreme Heat in Infants' and the Elderly

Infants and particularly those 65 years and older are physiologically more sensitive to high temperatures and also may be less able to protect themselves from extreme conditions.[66] Long-lasting heat waves (over several days) and, in particular, very warm nights that do not allow people to cool off, are particularly challenging for human health.[67] In the July 2006 heat wave, 20 individuals died of heat-related causes in the county.[68] Fresno County – in comparison with the state average – has a lower proportion of people 65 years and older, and the largest number of those currently in that age bracket live in the slightly cooler, higher-elevation portions of the county. The eastern/northern part of the county has the highest proportion of people over 65 years and up, which reaches 20% of the census track's population in these rural areas (Figure 12). However, in coming decades, the proportion of the older population is projected to increase

across the county, including in potentially hotter low-elevation areas.[69] They will require special attention in coming years to ensure they will be protected from extreme heat events.

Preexisting health conditions, many of which are found frequently among the elderly, can also increase sensitivity to the additional stress from heat. Interestingly, these preexisting conditions are not evenly distributed across the diverse population segments of the county. For example,

"Diabetes is one of the most pressing health concerns facing elder [San Joaquin] Valley Latinos; 44 percent have been diagnosed with diabetes as compared to 30 percent of elder Latinos across the state of California (CHIS, 2005). Only 19 percent of Caucasians in the Valley have a diagnosis of diabetes. Heart disease is the second most pressing health issue; 23 percent of elder Valley Latinos have heart disease compared to 18 percent of non-Valley Latinos. Asthma is yet another health issue faced by 18 percent of Central Valley Latinos, compared to 11 percent across the state (CHIS, 2005)."[70]

Moreover, the expected growth rate over the next few decades for each of the racial segments of the population suggest that the elderly Hispanic population will grow faster than others – precisely the portion of the population that is also experiencing the greatest incidence of diabetes, heart and pulmonary diseases. Fresno County (along with all the other counties in the San Joaquin Valley) "will experience at least a 350 percent increase [by 2040] in growth of the elder Hispanic population." [71] Thus, not only will heat extremes become more frequent and intense, but the population most sensitive to such extremes will grow more rapidly than any other.

Fresno County already provides information on how to stay healthy and safe during normal hot weather and extreme heat events in English, Spanish, and Hmong to reach dominant language group.[72] The county also has a heat contingency plan to help mitigate the impacts of heat in the summer months (starting in May), targeting especially vulnerable populations. Phase 1 of the plan takes an anticipatory approach, by starting an awareness campaign to distribute verbal reminders and written materials about the heat and how to mitigate its effects. In case of an actual heat emergency, the county implements Phase 2 of the heat plan, which involves opening cooling centers, providing transportation to those centers for those who need it, monitoring vulnerable populations, and other actions.[73] Augmented with social "buddy systems", such plans have proven effective in other regions.[74] As climate change extends the summer season and frequency of extreme heat events, and as the population grows older, periodic review can ensure adequacy of this system under changing conditions.

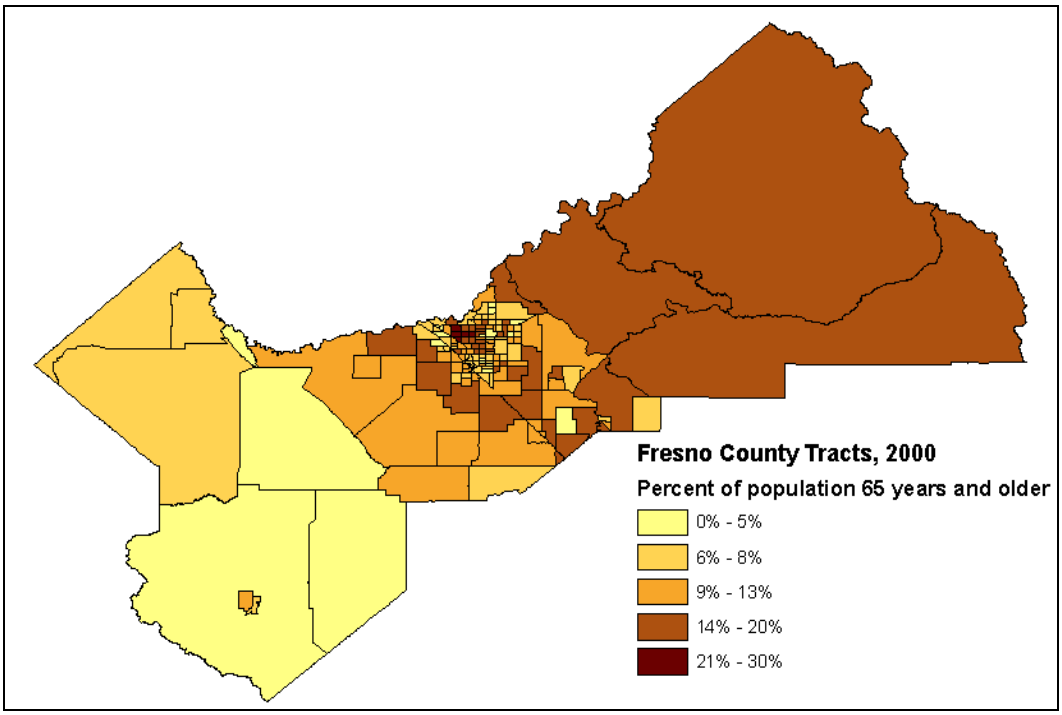

Figure 12: Percentage of the population 65 years and older

(Source: Census 2000)

Higher Sensitivity of the Elderly and Children to Air Pollution

In 2008, the Union of Concerned Scientists reported that air pollution kills more people than homicide in the San Joaquin Valley.[75] The San Joaquin Valley, within which a large portion of Fresno County is situated, is among the regions with the worst air quality in the country.[76,77] Ground-level ozone, particulate matter, and diesel soot are the main air pollutants, stemming largely from agricultural operations,[78] related industrial processes, combustion of wood and fossil fuels, construction and demolition activities, road dust, and transportation-related emissions (e.g., major routes such as Interstate Hwy. 5 and Hwy. 99) crossing through the county. [79,80,81]

The geography of the Valley contributes to air pollutants becoming concentrated in low-lying areas. Smog forms through the combination of air pollutants (e.g., nitrogen oxides (NOX) and volatile organic compounds) under the right weather conditions that are typical for the region (hot, sunny, low wind). As summers become hotter and drier in Fresno County with climate change, the production of surface level (i.e., human-damaging) ozone will increase.[82]

Ozone damages lung tissue and exacerbates existing respiratory problems.[83] And while air pollutants can be harmful to all exposed individuals, young children are especially sensitive to the adverse impacts of air pollution in that it leads to reduced lung function, increased incidences of respiratory illness, and increased respiratory symptoms.[84] One in six children already has asthma in Fresno County, twice the U.S. average and the highest rate in California.[85] The risk of pulmonary health problems in children is thus of particular concern.[86] Climate change may worsen these risks through direct and indirect factors causing air pollution, including:

- Higher temperatures increase the formation of ozone, a key component of smog;
- Climatic changes may extend the season for several allergy-producing grasses and trees;
- Climate change and related drought may increase the amount of fine dust in the air;
- risk of wildfire will increase in frequency and in total area burnt, thus increasing the amount of particulate matter in the air.

According to the 2000 Census, the proportion of young children is highest in the western, low-elevation, valley portion of the county where agriculture is the dominant land use and where the concentration of agriculture-related and other pollutants (ozone, particulate matter) is highest. Other areas with high concentration of children include the City of Fresno, some surrounding suburbs, and areas in the south-central part of the county (Figure 13). By contrast, the median age (Figure 14) is substantially higher in the eastern, mountainous portion of the county. Here, the main source of pollution can include ozone, and particulate matter from wildfire. An increase in wildfires, as is expected across mountainous regions of the state, including in eastern Fresno County[87], would add to this already existing risk and magnify the threat to those most sensitive to air pollution: the elderly and infirm. Particularly those with already existing respiratory problems are most sensitive to worsening air quality. A recent scientific study found that "individuals with asthma living in areas of the SJV [San Joaquin Valley] with high ozone and particulate pollution levels are more likely to have frequent asthma symptoms and asthma-related [Emergency Department] visits and hospitalizations."[88]

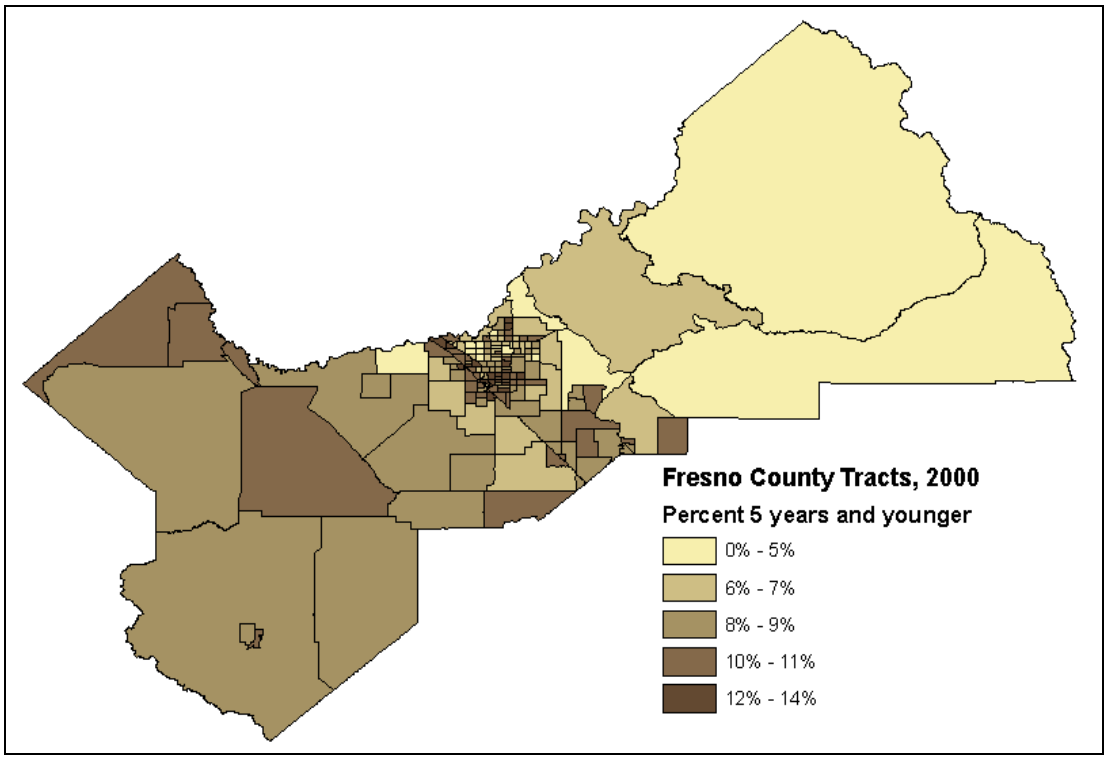

Figure 13: Children under 5 years old as percentage of total population

(Source: Census 2000)

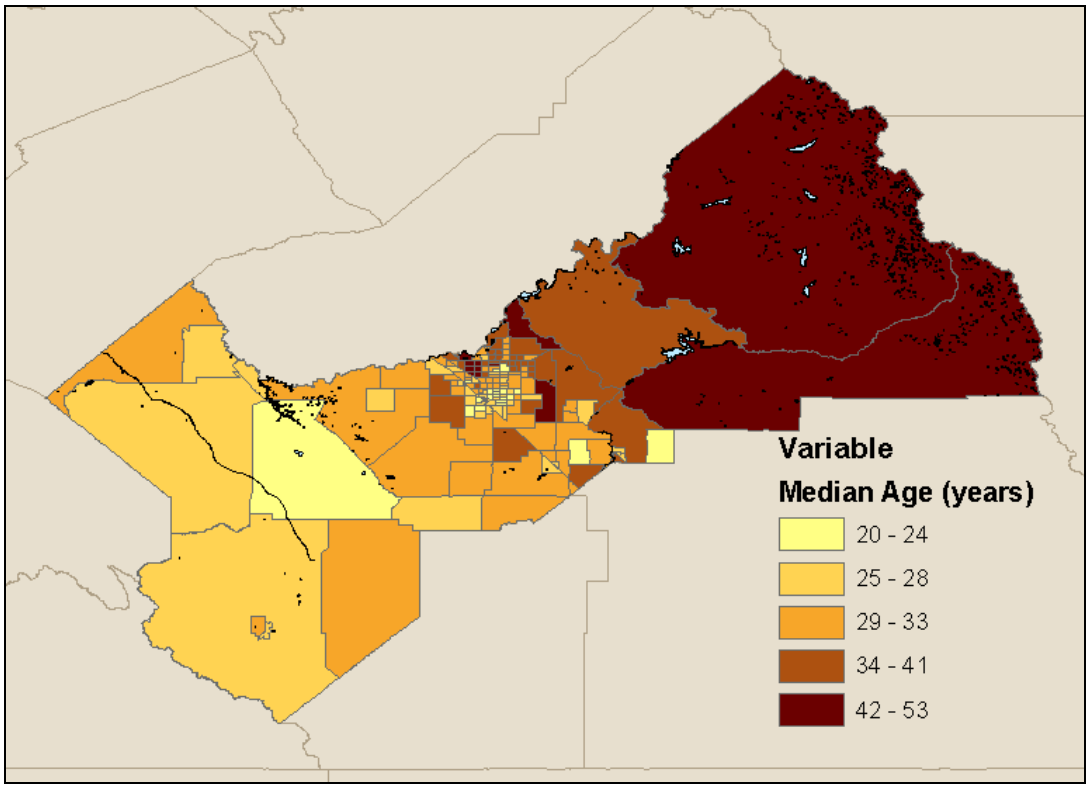

Figure 14: Median age by Census tract

(Source data: US Census 2000)

In some areas, Fresno County is already in nonattainment for particulate matter such as PM10 and PM2.5, and for 8-hour ozone federal and state air quality standards.[89] Meeting safe air quality standards as environmental and climatic conditions change, requires not just continued efforts to reduce existing problems, but ongoing monitoring, planning, extra efforts to reduce sources of air pollutants, and public education and outreach. Parents of young children, caregivers, educators, and public health officials may not be aware of how higher temperatures are worsening air pollution problems or how these sensitive populations can protect themselves during low-air quality incidents. Thus, it is important to explore adaptive measures for the county's growing proportion of sensitive populations.

2.3.3 Adaptive Capacity

Some populations are more vulnerable to climate change impacts because they are less able to cope with extreme events or make necessary changes. Common characteristics of these segments of society include poverty and low income, age, lower educational attainment, race, linguistic isolation, university students and other transient populations, and females as head of households.[90] These traits are common among large portions of Fresno's population, but also unevenly distributed across the county. Over the long term, the impact of both climate change and decreasing quality of vital natural resources (such as clean air to breathe and water to drink) will continue to burden those populations especially because they have a lower ability to

respond and deal with such changes.[91] Below are examples of characteristics that can lead to lower adaptive capacity for some populations.

Lower Income Correlates with Lower Adaptive Capacity

Lower income often correlates with lower access to the necessary resources to prepare for or evacuate in the case of an emergency, or to take the actions required to adapt to changing conditions (e.g., insulating one's house, elevating one's house above a given flood elevation). Countywide median per capita income in 2000 was estimated to be $15,495. The central and eastern portions of the county have the highest per capita income, while the northwest and small pockets in south central region have the lowest average per capita income (Figure 15). In 2008, the Census estimated that 22.1% of the county's population was living below the federal poverty level,[92] a figure considerably higher than the state average, which in turn is higher than the US average.[93] The Census survey for 2005-2007 showed that over 38% of the households countywide earn "extremely low income" or "very low income" when aligned with the Fresno County income categorizations provided in the 2001 Housing Element (Figure 16). The percentage of population that fit within the federal poverty income levels ranges from nearly none in some areas up to 68% in others (Figure 17). There is little or no data available for the poorest populations of the county, including those that have makeshift homes (cooking over fire, using a hose for showering etc.).[94] To the extent some of them are undocumented immigrants and workers, such data can be difficult to obtain.[95]

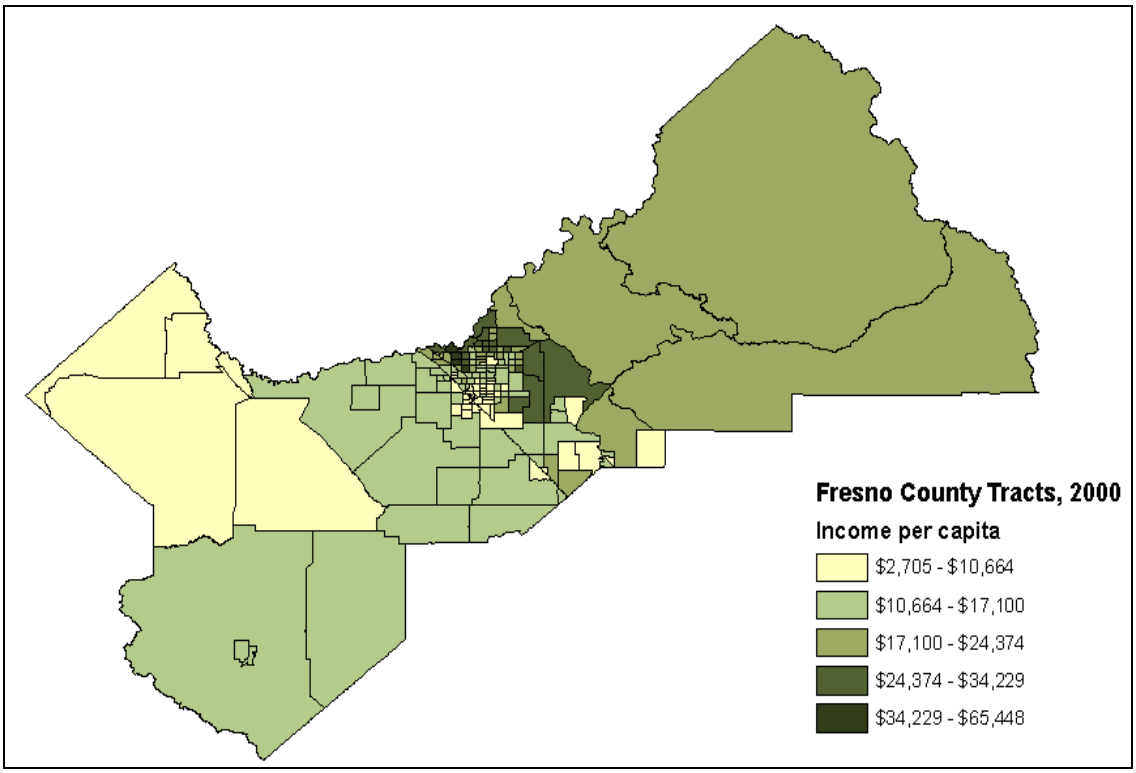

Figure 15: Per capita income by Census tract

(Source: Census 2000)

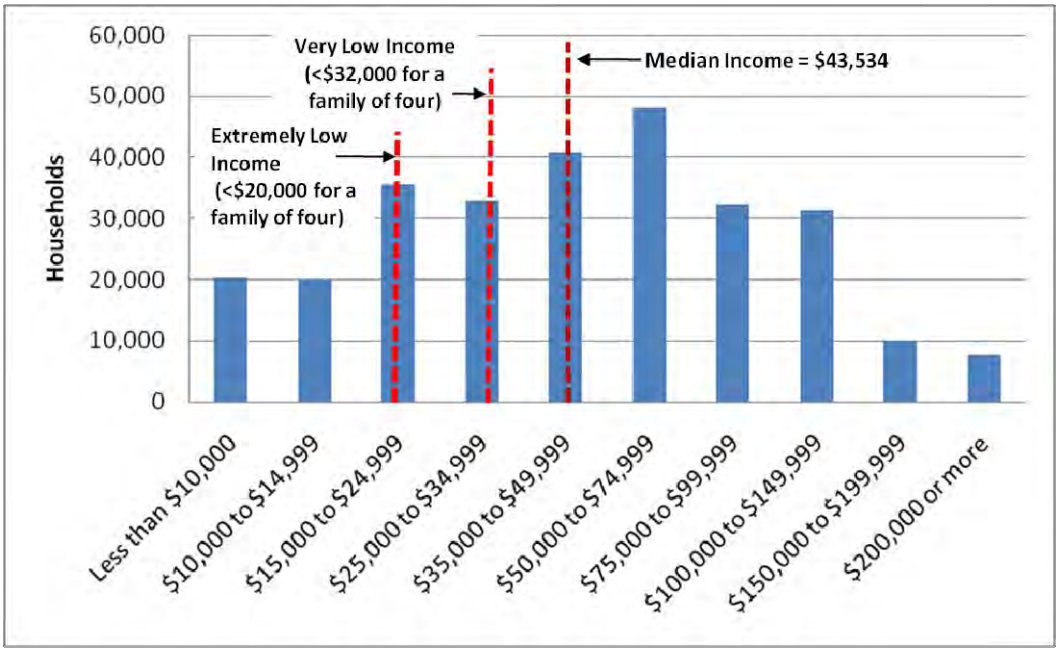

Figure 16: Countywide breakdown of household income with county-based income categories indicated with dotted lines

(Source: Income data and median income from US Census, American Community Survey 2006-2008[96]; income limit categories defined in Housing Element of Fresno County, March 2003[97])

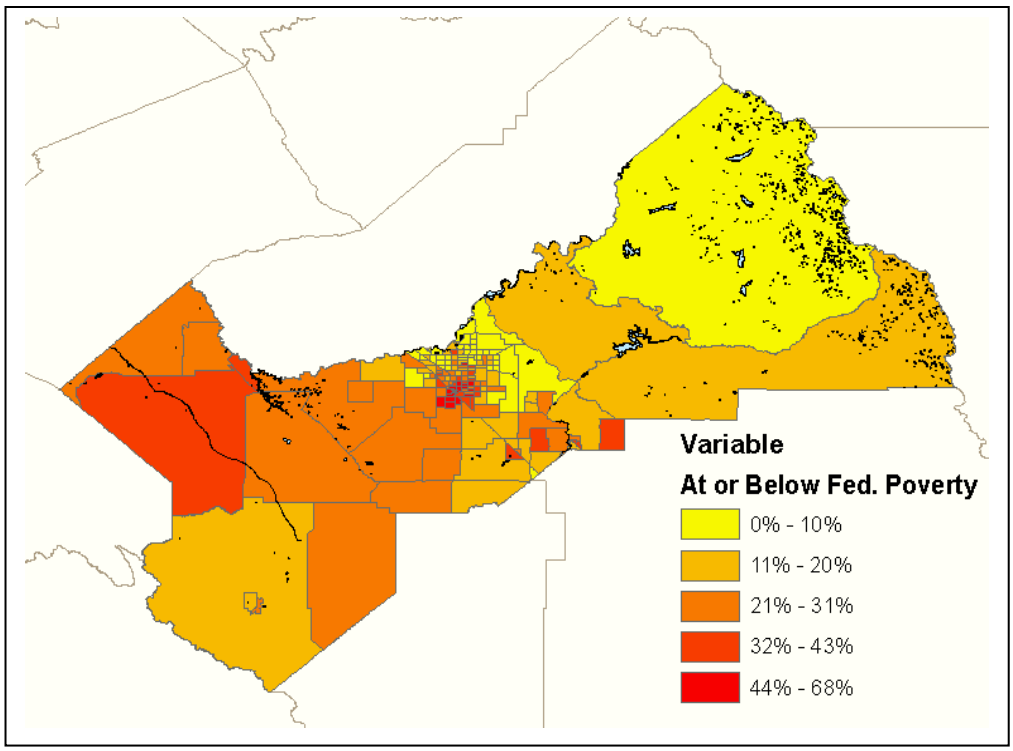

Figure 17: Percentage of persons living at or below the federally-defined poverty level by Census tract ($11,239 for a family of two; $17,603/year for a family of four) in 2000

(Source: Census 2000)

As of May 2010, out of a total labor force of 449,600, 15.9% (71,600) individuals were unemployed, a significantly higher rate than the state or national average.[98] High unemployment rates and income inequality are persistent and growing problems in Fresno County, as the poor are getting poorer and the wealthy are getting wealthier. Part of the reason for high poverty in the county is the high proportion of low-wage workers (see also the section on low education levels below). For example, many in agriculture depend on seasonal, low-wage jobs and collect unemployment during the off-season. "The top 10 occupations with the greatest number of jobs projected between 2004 and 2014 by the EDD [California Economic Development Department] are primarily low-wage positions, requiring short-term on-the-job training, with the exception of registered nurses."[99]

The growing disparity between income brackets creates social friction and isolation of social groups from each other, undermining the sense of community and mutual support that is needed to meet the challenges of the future. Extreme poverty and generally low levels of wealth undermine the ability of families and communities to take proactive steps, and when disasters strike, they are largely dependent on support from outside (state and federal sources).[100] Low income thus is one of the most important indicators of limited adaptive capacity,[101] and can be addressed through special needs-related programs or by creating opportunities for low-income populations to make a better living (e.g., through education and training programs, providing a living wage, diversifying the economy). These strategies are consistent with the Blueprint

Vision of a prosperous Fresno County, based on world-class education, vibrant, attractive communities, and a more diversified economy.

Lower Education Can Undermine Adaptive Capacity

In some studies, lower educational attainment correlates with lower adaptive capacity to deal with extreme events.[102] Possible connections between education and the ability to deal with disasters and change include lower wage- and salary-earning capacity, and thus lower income; a lower capacity to obtain and understand emergency preparedness and response information, lack of access to health care, and various types of insurance (e.g., fire, flood, and health insurance), some degree of disenfranchisement from society, and so on.[103] Figure 18 shows the distribution of individuals (by proportion) in each Census tract over 25 years old that have not graduated from high school. In terms of education, 67.5% of the population 25 years and older as of 2000 were high school graduates (compared to 76.8% statewide) and 17.5% of this same age group had a bachelor's degree or higher (compared to 26.6% statewide) (Figure 19).[104]

People with less education require a higher level of attention and assistance than those with greater resources of their own from public agencies. Community centers or organizations specifically serving these low-education, poor neighborhoods may serve as important "go-betweens" between government agencies and the individuals in need. As the next section will show, the same areas in the county that are hit hardest by poverty and low levels of educational achievement, are also predominantly Hispanic/Latino communities. Thus, much of the necessary outreach, education, and assistance should involve and be directed toward the Hispanic/Latino population and its leaders.

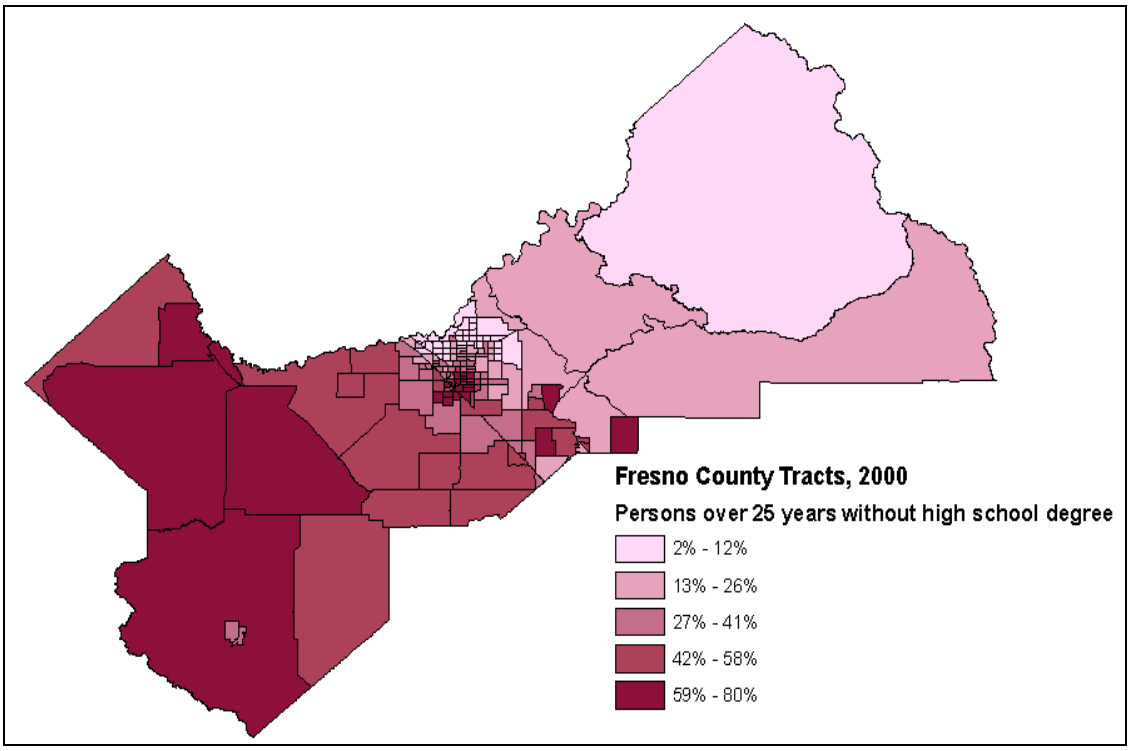

Figure 18: Percentage of individuals over 25 years old that have not graduated from high school

(Source: Census 2000)

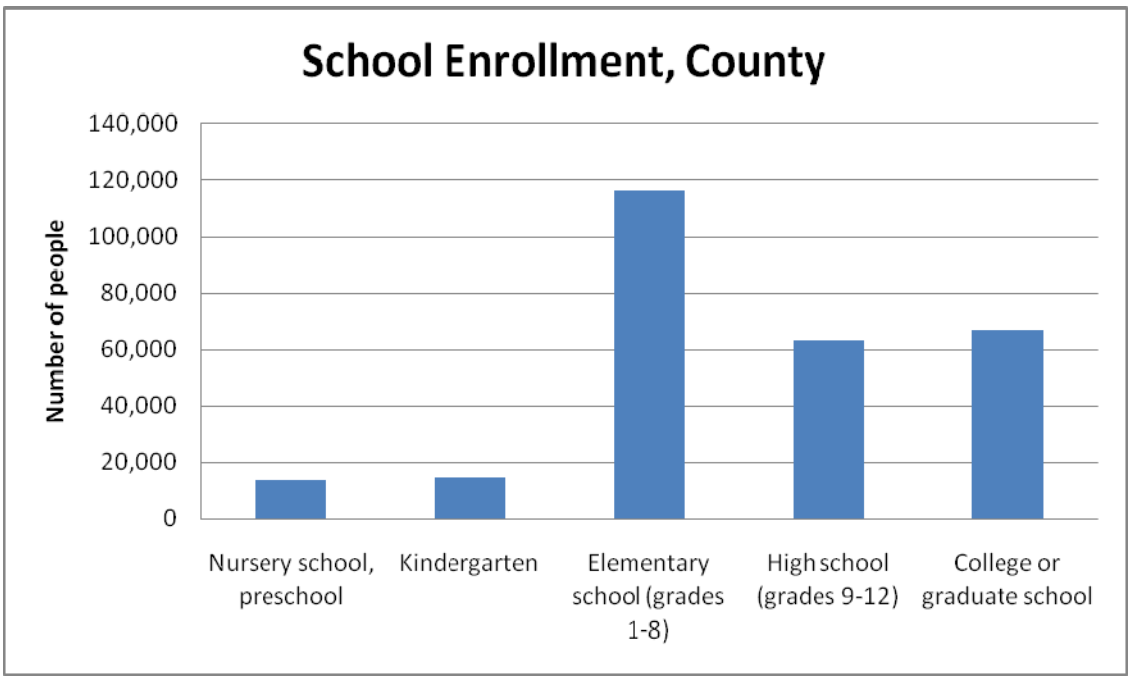

Figure 19: Number of people enrolled in school by grade level in Fresno County

(Source: Census, American Community Survey 2006-2008[105])

Race and Environmental Injustice in Adaptive Capacity

Studies of vulnerability to disasters repeatedly indicate that minority populations tend to have lower capacity for responding to disasters and adapting to climate change than non-Hispanic whites.[106] As indicated above, the countywide racial makeup in 2008 was predominantly 48.7% Hispanic/Latino, white 35%, 8.5% Asian, 4.9% African American, and 2.0% American Indian.[107] Figure 20 shows the geographic distribution of Hispanic/Latino, African American, and Asian segments of the population.

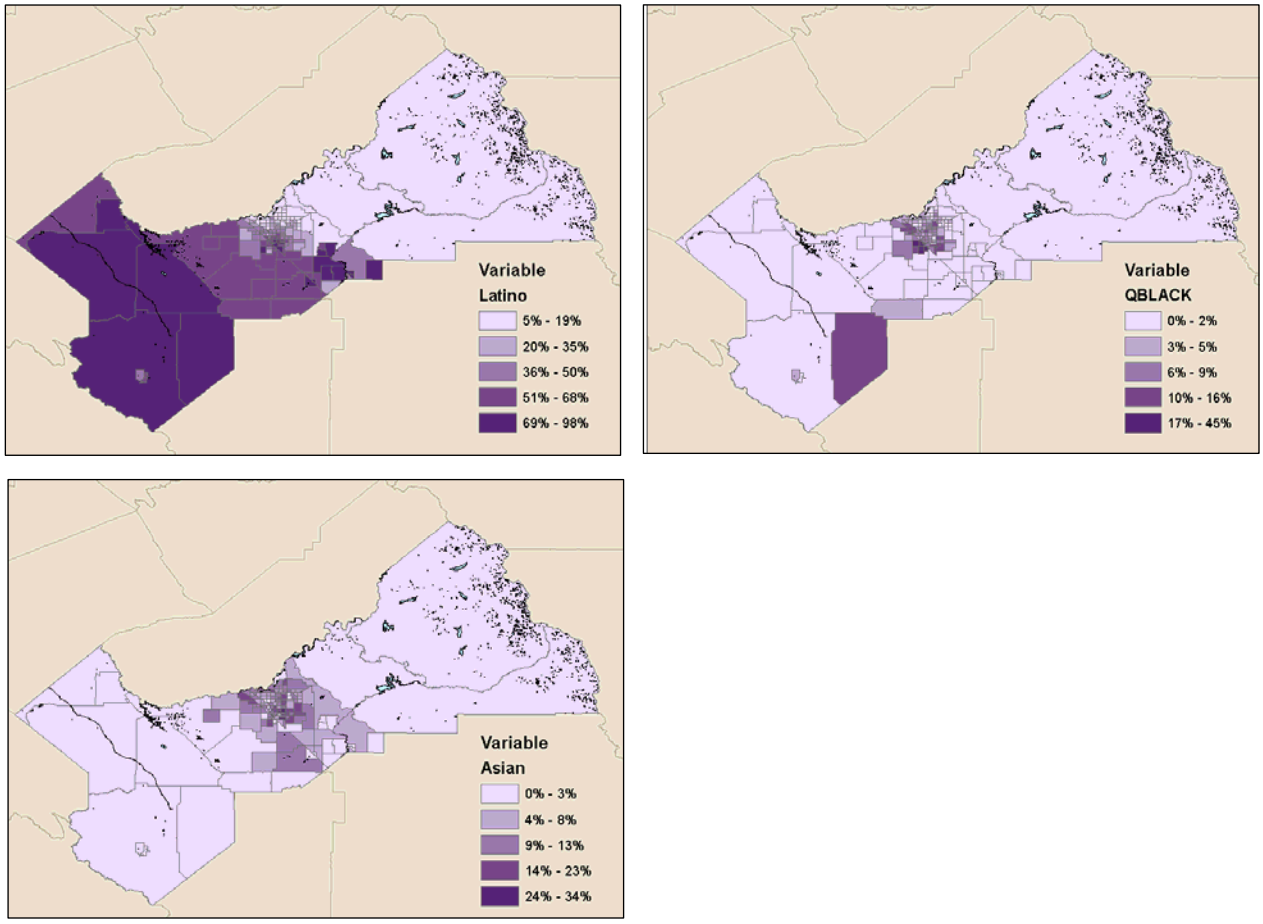

Figure 20: The geography of race in Fresno County by percentage of the total population

(percent of the Hispanic/Latino population, upper left; percent of the African American population, upper right; percent of the Asian American population, lower left) (Source: Census 2000)

The most likely reason for the correlation between race and lower adaptive capacity is the disproportionate amount of poverty and often lower incomes among African Americans and Hispanics compared to white segments of the population. In minority populations where English is not the first language spoken, linguistic proficiency can also play a role. Other factors, such as being tightly socially connected, may compensate to some extent (see below). According to the U.S. Census, a significant portion of the Latino/Hispanic population resides predominantly in the western region of the county and also in the southeastern parts of the central region.

Farm workers are one group of the population in Fresno especially disadvantaged in terms of adapting to climate change. A statewide study of farm workers estimated that in 2000 there were approximately 113,741 migrant and seasonal farm workers in the county; including other members of the families of farm workers, the total number was 202,404, the highest for all counties in the state.[108] A UC Davis study on California farm labor estimated that 91% of

farmworkers in California are from Mexico.[109] The Fresno County 2001 Housing Element reports that,

"Farmworkers have the lowest family income of any occupation surveyed by the Census Bureau and the highest poverty rate of any surveyed occupation. Farmworkers have the lowest educational attainment and are second from the lowest, after the private housekeeper occupation, in home ownership. Farmworkers have one of the lowest rates of health insurance coverage and are overwhelmingly non-citizens (including legal residents, workers with a permit, or undocumented)."[110]

The Latino/Hispanic population thus experiences a multitude of disadvantages – low-level educational achievement, high levels of poverty and seasonal unemployment, disproportionate incidence rates of diabetes and other diseases, and so on. Moreover, the majority of the Hispanic population lives in the hotter part of the county and works in agriculture. As outdoor workers, especially if they have little or no say about their working conditions and hours, they are at higher risk of being exposed to extreme heat and air pollution, both of which are projected to become more frequent and severe as climate change progresses.

A health study conducted in the City of Parlier found that 28% of farm workers were not counted by the Census "because they lived in unofficial dwellings"[111] (see also a report on the challenge of accounting for and reaching undocumented works through health services).[112] Low income and high poverty rates make it difficult for this population to afford adequate housing and access transportation. According to one report, "Throughout the Fresno County Environmental Justice Planning process, the question of affordable and obtainable transportation within the Fresno COG transportation planning process has come up time and time again."[113] Substandard housing with little insulation, even if it has an air conditioner, may require constant air conditioning, which reduces health-related risks from heat, but is expensive for homeowners and renters, and produces (to the extent the needed electricity is produced using fossil fuels) more air pollutants and heat-trapping gas emissions. Thus the most immediate response to help cope with more heat actually makes the ultimate problem worse (see Dealing with Heat Stress[114]).

Dealing with Heat Stress: Prevention, Emergency Response and Addressing Underlying Causes

Health officials in California suggest there are many things individuals can do to protect themselves from the adverse effects of extreme heat, especially prolonged heat wave events, including:

- Reduce activity level (especially outdoor sport, gardening etc.)
- Seek air conditioned or cool, shaded, well-ventilated locations (e.g., public buildings)
- Drink plenty of hydrating fluids (non-alcoholic and not-caffeinated beverages)
- Take cooling baths or using ice packs to cool down the body temperature

In addition, public officials can assist individuals by setting up special heat health warning and assistance programs which ensure that:

- People have available and can access cooling centers
- Laws protecting outdoor workers are properly implemented (Figure 21)

- Low-income households obtain financial assistance from electric utilities
- Elderly, infirm, alone-living and socially isolated individuals are frequently visited and their health is monitored
- Educational materials are provided in all necessary languages and at the appropriate competency level

Communities also can make their towns cooler with strategies that are entirely consistent with the vision and strategy of the Valley Blueprint, for example:

- Plant shade-giving trees near buildings
- Install cool, reflective roofs
- Use cool and light-colored paving materials

The deepest solutions involve efforts to reduce heat-trapping greenhouse gas emissions and thus future warming globally, as well as comprehensive interventions by all levels of government and the private sector to reduce the vulnerability of the most exposed populations through promoting overall health, well-bring, income levels, education and social integration.

Figure 21: Farmer worker taking a break to rehydrate while working in the sun-exposed vineyards.

(Source: Rani Mclean)

Language and Cultural Isolation Reduce Adaptive Capacity

In some instances, immigrants born outside the United States and/or individuals not fluent in English may be culturally and linguistically isolated, at least from some government institutions and English-language dominated business opportunities. Among other social and economic disadvantages, this cultural and linguistic isolation can make it difficult to access or receive important information about preparing for and responding to weather- and climate-related emergencies. In 2000, 21.1% of the county's population was foreign born compared to the State's 26.2%, and Census estimates for 2008 suggest this percentage has remained nearly consistent for the county.[115,116] The Census estimates show that of the foreign-born population, 76.2% entered before 2000 (i.e., they have been here for at least ten years, giving them time to get settled, learn English, and build a community support network). Of the foreign-born population, 68.4% (129,705) are not U.S. citizens.[117] Of the population 5 years and over, the Census estimates that

in 2006-2008 there were 333,526 individuals in Fresno County that spoke a language other than English at home. Of these, 149,164 spoke English less than "very well" (Figure 22). Most of those speaking English less than very well were Spanish speakers (116,919), but also a high number of those speak Asian and/or Pacific Islander languages (22,098).[118] The greater Central Valley is home to the highest concentration of Lao and Hmong refugees in the United States who resettled here during and after the Vietnam War, with estimated 80,000 Hmong and over 15,000 Lao.[119] The first generation immigrants (many of whom are now over 65 years old) tend to be linguistically isolated and there are few medical services provided for this population. Reaching this population is also especially important given that their cultural beliefs and isolation from western science and education may make them vulnerable to the impacts of climate change.

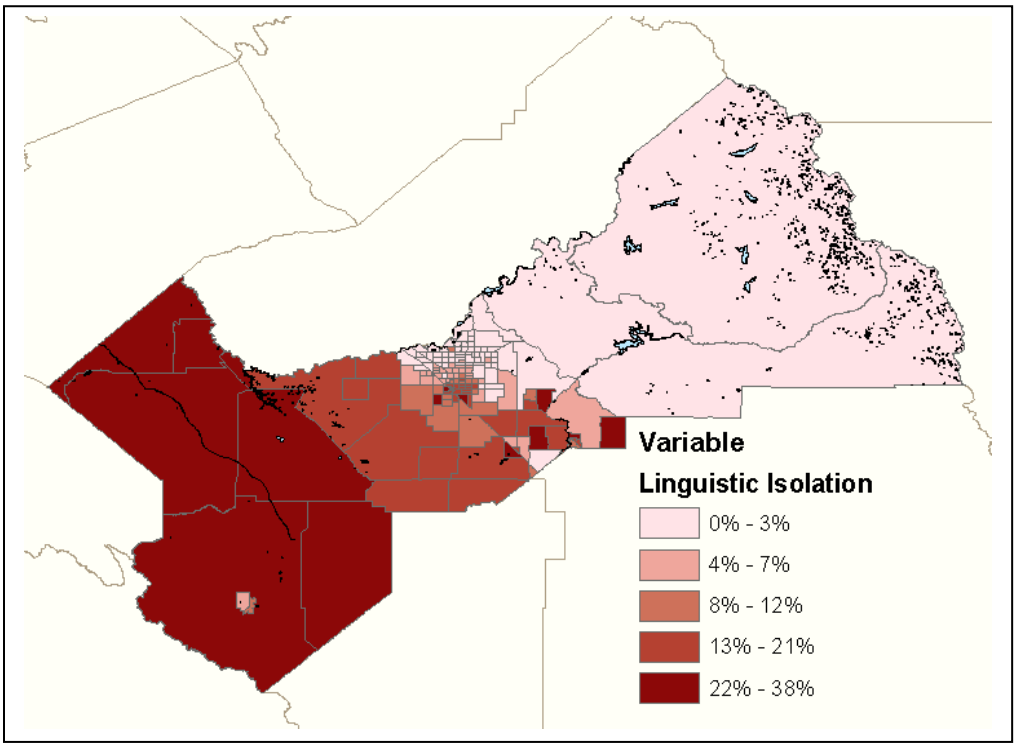

Figure 22: Percentage of Fresno's population (per Census tract) that speaks English "less than very well"

(Source: Census 2000)

Given the high proportion of Spanish-speaking individuals in the county, many social and government services are already provided bilingually. As the county implements its Valley Blueprint, cognizant of the additional challenges related to managing the unavoidable impacts of climate change, it is especially important that adaptation planning not neglect these populations and provide them with necessary information, services, and engagement opportunities in their native language or with translators. For example during weather- and climate-related disasters, these individuals may require essential information in the language most easily understandable to them; after disasters, non-native speakers may require special

assistance working through difficult-to-understand disaster assistance applications and so on. Relatively new arrivals in the community may not yet be socially connected and thus be easily forgotten, not noticed, and they may not yet be familiar with available services. Many of the county websites provide information in both English and Spanish, and it is important to maintain such bilingual information in the future through the internet and other public outreach efforts.

Lower Adaptive Capacity: Limited Mobility of the Elderly during Disasters

Age can also play a role not just in sensitivity but also in adaptive capacity. For example, the elderly are considered to be more vulnerable in emergency situations because of possible mobility challenges (Figure 12).[120] As mentioned above, there are higher concentrations of elderly within the eastern region of the county. When looking at the Census tracts, this age group ranges from ~0-30% of the total population.[121] A Census tract on the north side of the City of Fresno has the highest proportion of the 65 and older age group (30%). In Sentinel, Shaver Lake, Prather, and other eastern region towns near and in the Sierra Nevadas, the 2000 U.S. Census shows that more than 15% of the people living in this area were 65 years and older. This region's communities may be of particular concern during climate- and weather-related disasters (e.g., wildfires) because it is relatively remote, emergency response times are long (see below) and individuals themselves may be less mobile without outside assistance.

Figure 23: Elderly individuals living in forested, mountainous areas of eastern Fresno County may be difficult to reach and may have difficulty responding and moving quickly in case of emergency

(Photo: FEMA)

Housing and Control over the Living Situation

Housing ownership also tends to be a factor in adaptive capacity. Home ownership versus renting is often related, again, to income distribution. However, with regard to adaptive capacity, it also indicates how much control individuals have over their housing, for example, to make structural adjustments to their home for flood protection or insulation from heat, or whether they are able to modify vegetation surrounding the house (a form of protection from wildfire).

In 2008, the Census estimated that there were a total of 279,029 housing units in Fresno County. The median price of a house sold during the period from 2006 to 2008 was $286,800 although this varied considerably by place with higher prices typically found in the eastern county region, such as Centerville near the edge of the Sierra National Forest (Figure 24).[122] There were an estimated 45.3% renters countywide, albeit with considerable variation: 78% to the southwest of the City of Fresno to as low as 2% in the Woodard Park area (just north of Clovis). The high proportion of renters may be attributed to the overall lower income, especially among farm and service industry workers.[123] Other concentrations of renters can be found in the more populated areas around the City of Fresno, which is also the home of the California State University-Fresno, with a high student population (see below for more discussion of that particular population) Figure 25).

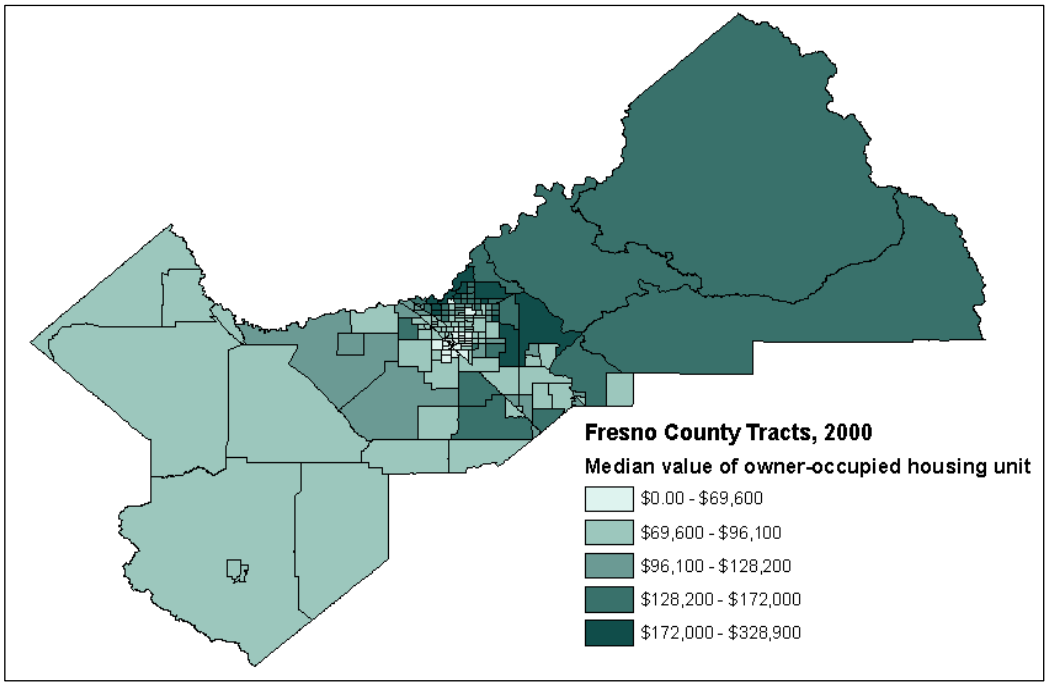

Figure 24: Median house value

(Source: Census 2000)

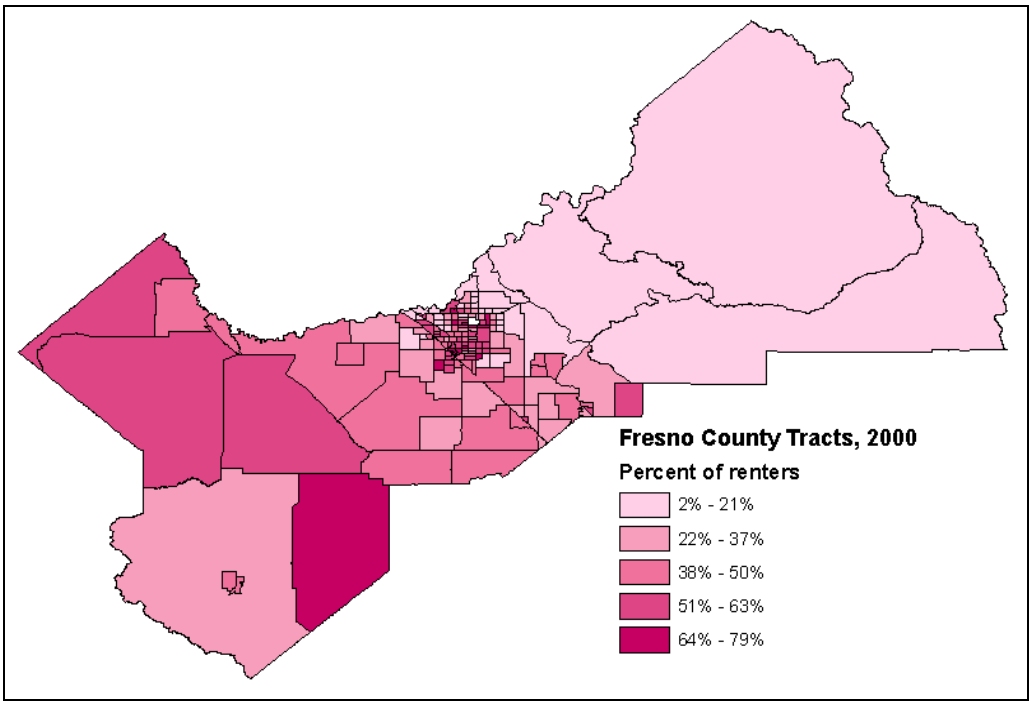

Figure 25: Percentage of occupied housing units that are rented

(Source: Census 2000)

Another common indicator of vulnerability is the number of persons per household (Figure 26), as it indicates not only low income, but can also imply higher exposure (individuals per unit of space) and closer proximity in which diseases can be more easily transmitted.

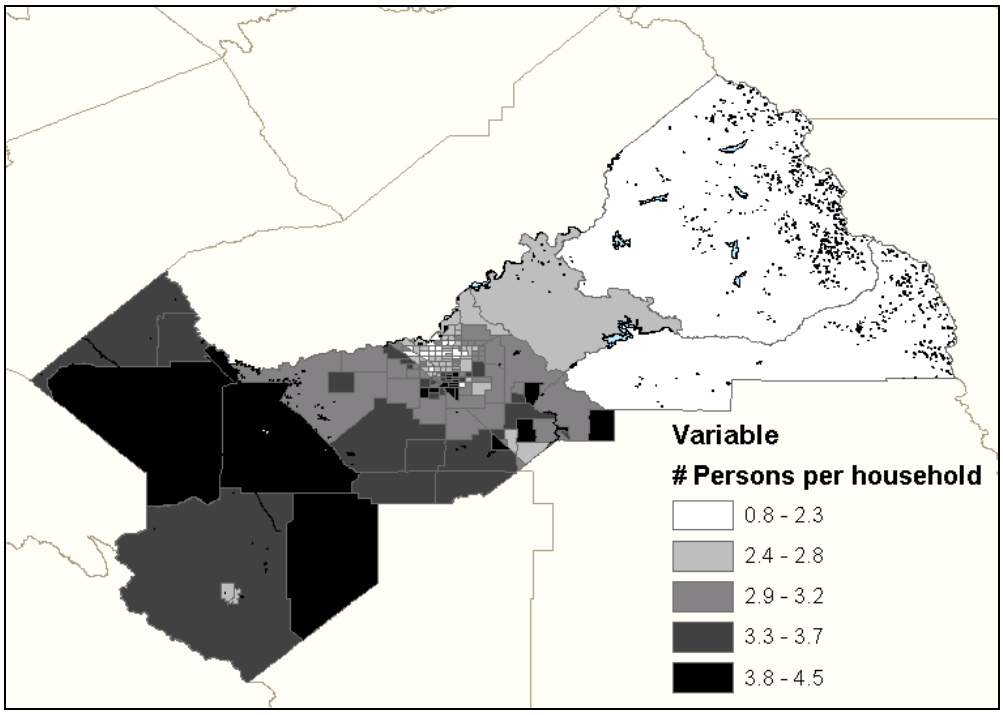

Figure 26: Number of persons per household in Fresno County

(Source: Census 2000)

Of particular interest with regard to vulnerability is the homeless population. The General Plan presents findings from a study on homeless in Fresno County, finding that there were over 5,000 homeless persons living in the county.[124] These populations are especially vulnerable to adverse weather because they do not have homes to provide necessary shelter. Heat waves are already an existing problem for the homeless population in Fresno County. Given that climate change is projected to produce higher temperatures and the number of extreme heat days in the region, it is important that adequate cooling centers be provided to accommodate this population to prevent health risks from heat exhaustion and dehydration. While it is assumed that the majority of the estimated 5,000 homeless persons are living in the cities, this assumption is difficult to validate, and has not been empirically confirmed, due to the challenges involved in locating and surveying such populations.[125] Therefore, more research is needed to more accurately identify the current extent of homelessness and to devise appropriate strategies to reach and protect this vulnerable population.

In terms of housing needs, there is already a lack of affordable rental housing for residents and this problem "is likely to become worse as rapid population growth continues."[126] This means that many residents may be spending a high proportion of their income on rent and food, making it difficult to have extra resources as a safety net that would provide security in times of an emergency (e.g., for preparing prior to, mitigating impacts of, and responding to, climate change- and weather-related extremes or health impacts of climate change).

Of Special Concern: Students and Institutionalized Populations

In studies of disaster vulnerability, university students have been found to be of particular concern, and sometimes special disadvantage. Students – especially those based far from home (especially foreign students) as a unique category of the population that is transient) – tend to live apart from their families and to be disconnected from their resident community. [127] In other ways students may be better connected during disasters because they are linked to a single institution that can easily inform them anf focus preparedness and disaster response operations. At the same time, they may not own vehicles and may have a lower response rate to public warnings about emergencies. While Fresno County's college student population is not huge, it is significant enough to warrant attention (see Figure 19 above). As of fall 2009, 21,500 students were enrolled at CSU-Fresno, located in the City of Fresno.[128] The majority of students are from Fresno County with 56% of the enrollment in 2007 from Fresno County, 26% from other parts of the Central Valley, 15% from outside of the Central Valley in California, and the remaining 3% from outside California (elsewhere in the U.S. or international origins).[129] The influence of isolation from family on student's low adaptive capacity is magnified by another factor: students tend to be renters when they live away from their families and thus have lower control over their housing situation. On-campus housing at CSU-Fresno may require special evacuation and disaster preparedness plans to account for students' special situation. The county has three other colleges: Fresno City College, West Hills College Coalinga, and Reedley College, the latter of which is located in the 100 year flood zone as marked by the County Local Hazard Mitigation Plan.[130] These are Junior and Community Colleges, where the situation may be slightly different: students are predominantly from the area and may live either with or near their families.

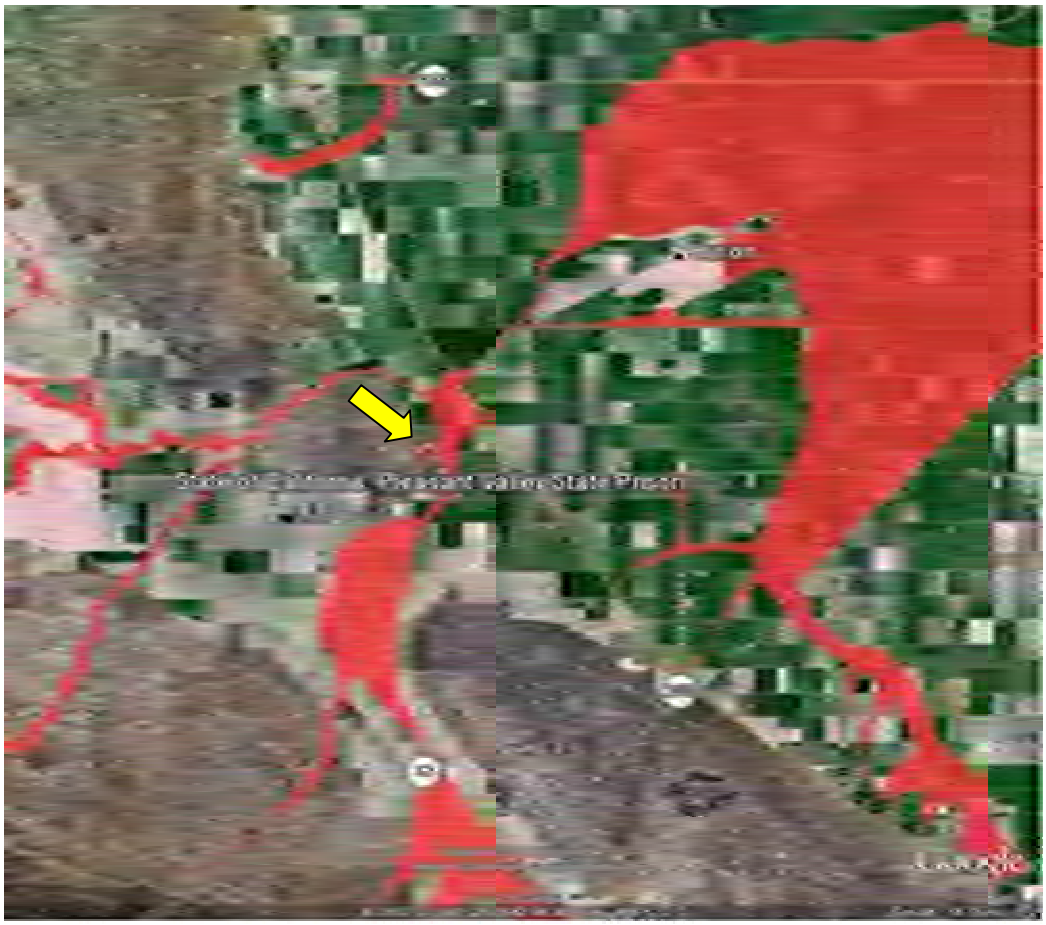

Figure 27: Map of flood zones designated by FEMA in 2009 (high risk flood is shown in red, moderate and low risk flood zones are shown in pink), indicating the State Prison's location adjacent to a high risk flood zone (yellow arrow)

(Source: Data from FEMA, mapped in Google Earth)

Institutionalized populations are reliant on institutional provisions and the facility's response measures during times of disaster for support. Fresno County has one state prison, Pleasant Valley State Prison, which has approximately 5,188 inmates.[131] This prison is located off Interstate 5, to the west of Coalinga and just north of Kettleman City. Although the prison is not located directly in a flood zone, it is adjacent to a high risk flood zone (Figure 27). Extreme runoff and flooding events may increase in the future if high rainfall and runoff events coincide. Thus, the emergency response capability of the prison should be reviewed in light of changing flooding risks under climate change.

Community Organizations and Social Capital: Enhancing Adaptive Capacity

Social groups can be important resources for communities in cases of emergency by providing resources and support as well as by helping increase public awareness about what households and communities can do to cope with and adapt to the impacts of climate change. Trustful social relations are among the most important immaterial resources during times of stress and

change. For example, community organizations (such as faith communities, civic organizations, neighborhood associations, social clubs and unions) can distribute information and help educate each other by holding trainings, seminars, or informal gatherings. Through such events and dialogues, social groups can develop strategies for helping individuals and families to become familiar with the risks, take actions to reduce their exposure, assisting targeted populations during emergencies (e.g., a social buddy system during heat waves), and support each other in the aftermath of disasters to rebuild and bounce back more quickly.

Fresno County is rich in social organizations, including clubs, interest-based associations, and religious communities. Some 55.5% of the population identifies as religious and over half the religious population is Catholic.[132] The county has 40 rapidly growing Catholic congregations with a total of 232,565 adherents.[133] The second most dominant religious affiliation is Evangelical Protestant with 94,156 adherents. Churches often serve as safe areas for evacuees in times of disasters, such as wildfires and flooding events. They provide emergency services, food, shelter, information, and social, emotional, and spiritual support. Some may be particularly well positioned to reach into otherwise linguistically or culturally isolated segments of the population (e.g., especially Catholic churches with high Hispanic/Latino membership may be able to help get information about disaster preparedness and coping strategies to Spanish-speaking community members).

In addition to churches, the county has many other organizations with the mission to help communities, advocate for certain populations, and provide support networks for the most vulnerable. These include, but are not limited to, Fresno Metro Ministry, Fresno Center for New Americans, Coalition for Clean Air, UC Coop Extension Young Nutrition Education Program, Center for Economic Research and Education of Central California (research program, CSU-Fresno), California Rural Legal Assistance, and many more. These groups could play active and necessary roles as adaptation planning and the implementation of the Valley Blueprint move ahead.

2.4 Summary

In summary then, we integrated 32 Census variables associated with low adaptive capacity and high sensitivity to climate-related impacts. The result is an integrated picture of social vulnerability across Fresno County (Figure 28). This analysis was conducted following the well-established methods developed by Susan Cutter and colleagues (2003). They usea set of social variables that are known for their association with social vulnerability to disaster response and recovery.[1]

Based on this analysis, the most vulnerable populations are located predominantly in the western region, with some in the southeast also indicating medium vulnerability. The population in the western portion of the county is characterized by low educational attainment, high proportion of Hispanic/Latino people, high poverty and low income, high agricultural employment (low wages, outdoor workers), high number of people per household, high proportion of people that speak English less than well, and a high proportion of the population with young children. This region is largely rural, with many communities residing in

[1] Specific results and a summary of the methods used are presented in Appendix A.

unincorporated parts of the county and therefore without access to kinds of services commonly available in cities (such as central sewage systems or excellent health care facilities). These areas are also prone to street flooding or are downstream of inundation in cases of dam failure, the risk of which may increase with climate change due to the likely increase of higher runoff earlier in the year. The higher vulnerability on the southeastern side of the county reflects the relatively high proportion of elderly, which tend to be less mobile in cases of emergencies and more sensitive to extreme events. While this southeastern area is largely covering the foothills and mountains and therefore does not get the same heat waves that the valley endures, this area is especially at risk of fire threat (see Section 4) due to its steep slopes and forested terrain.

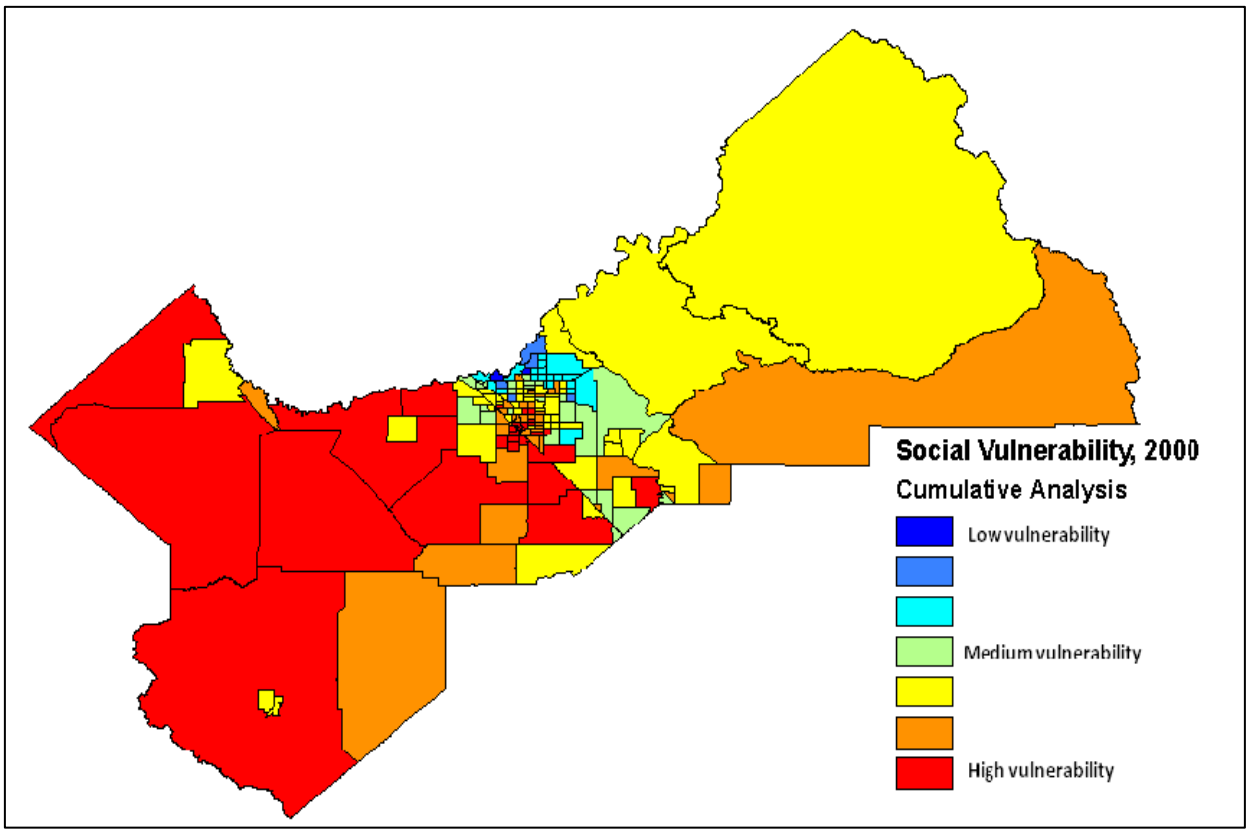

Figure 28: Social vulnerability map integrating 32 Census variables associated with low adaptive capacity and high sensitivity to climate-related impacts. Areas determined as most vulnerable include nearly the entire western portion in the county, much of the urban are in the central region, and a large Census tract along the southeastern edge of the county (into the Sierra Nevada Mountains).[134]

Section 3: Economic Sectors and Activities of Fresno County

3.1 Overview of Economic Sectors in Fresno County

Fresno County's economy is dominated – in terms of employment – by service industries (retail, transport, distribution, food services, medical services, education, etc., [see Figure 29]) and agriculture with its related industries, such as food processing and packaging (see Figure 30). Trades and government comprise other major employers in the county (Table 3).[135]

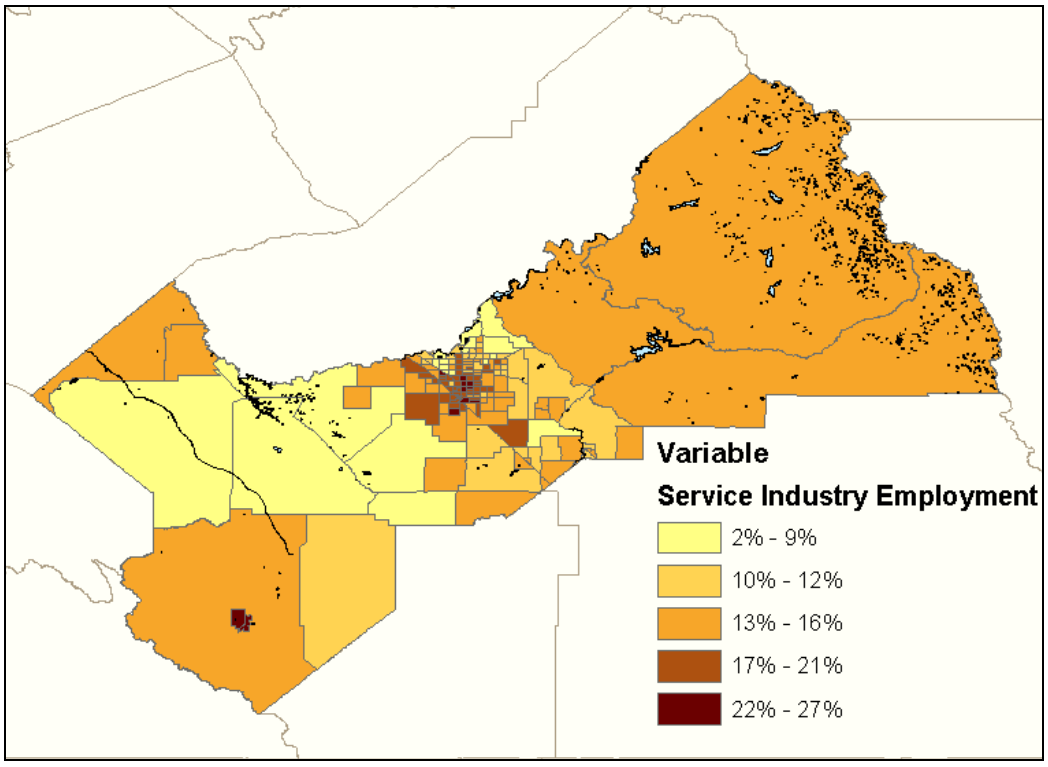

Figure 29: Employment in the service industry

(Data source for map: US Census 2000)

Different areas of the county can be distinguished by the different economies that dominate in each. The northwest portion has mainly large-scale farming with both permanent crops (on the east side) and row crops (on the west). West of I-5 in the county along the foothills is primarily used for grazing.[136] The southwestern side (with the cities of Huron and Coalinga as its main urban centers) is similar to the northwest region, but has additional economy of mining and petroleum industries. The valley region (regarded as the "East Valley Market Area" in the County Housing Element) contains the major population centers of the county. In the rural part of this valley region is the highly productive farmland. Lastly, the Sierra Nevada (eastern portion) of the county is mountainous, much of which is public land. Communities here are

decentralized and there is little agriculture because of the terrain (except for some grazing land). Recreational activities, such as vacationing (with a significant number of second homes), hiking and camping, attracting tourists on their way into Sequoia, Kings Canyon and Yosemite National Parks are more prevalent in this region.

Table 3: Employment per Economic Sector

(Employed as Percentage of Total Employed)

Economic Sector	Employment (% of total)
Service Industry	21%
Agriculture Industry	21%
Trades	19%
State & Local Government	16%
Manufacturing	8%
Construction & Mining	5%
Finance, Insurance, Real Estate	4%
Transportation & Utilities	4%
Federal Government	3%

Source: California Department of Finance, California County Profiles, February 2001 (based on 2000 data)

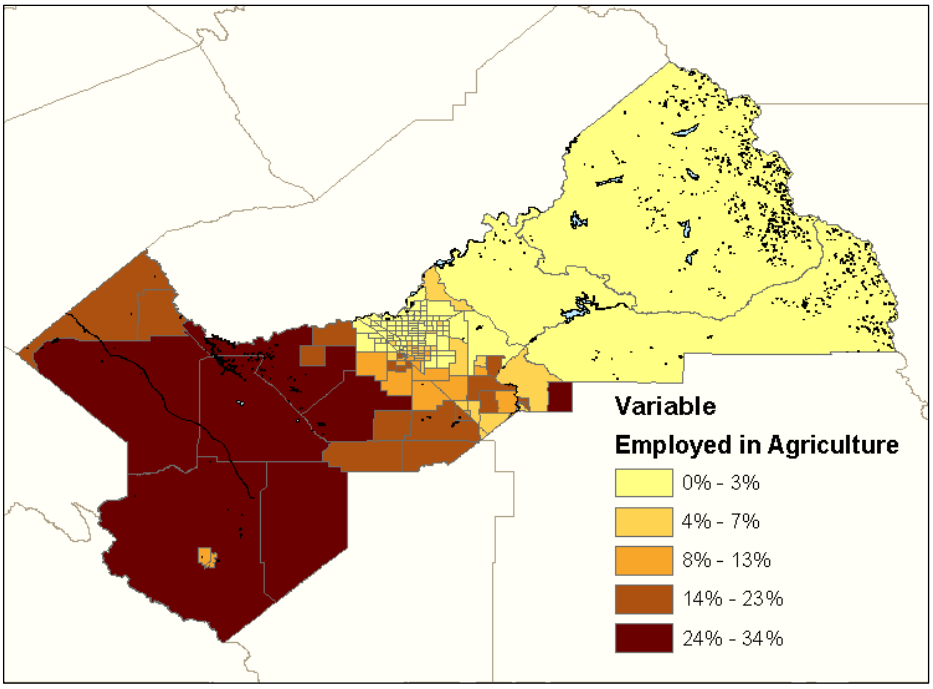

Figure 30: Employment in agriculture is more dominant in the western regions of the county

(Data source for map: US Census 2000)

In recent years, Fresno County has been hit especially hard by the economic downturn, with an unemployment rate (16%) that is substantially higher than the state's average (12%).[137] The U.S. Department of Labor reported that Fresno Metropolitan Statistical Area had the seventh highest unemployment rate (17%) in the country in June 2010.[138] Due to the nature of the agricultural economy and its seasonal employment highs and lows, Fresno and other Central Valley counties consistently have a higher than state average unemployment rate. As Figure 31 below shows, unemployment is generally high in the early months of the year but clearly drops from July through September and then returns to the higher rates in late fall when less farm labor is needed for picking and processing.

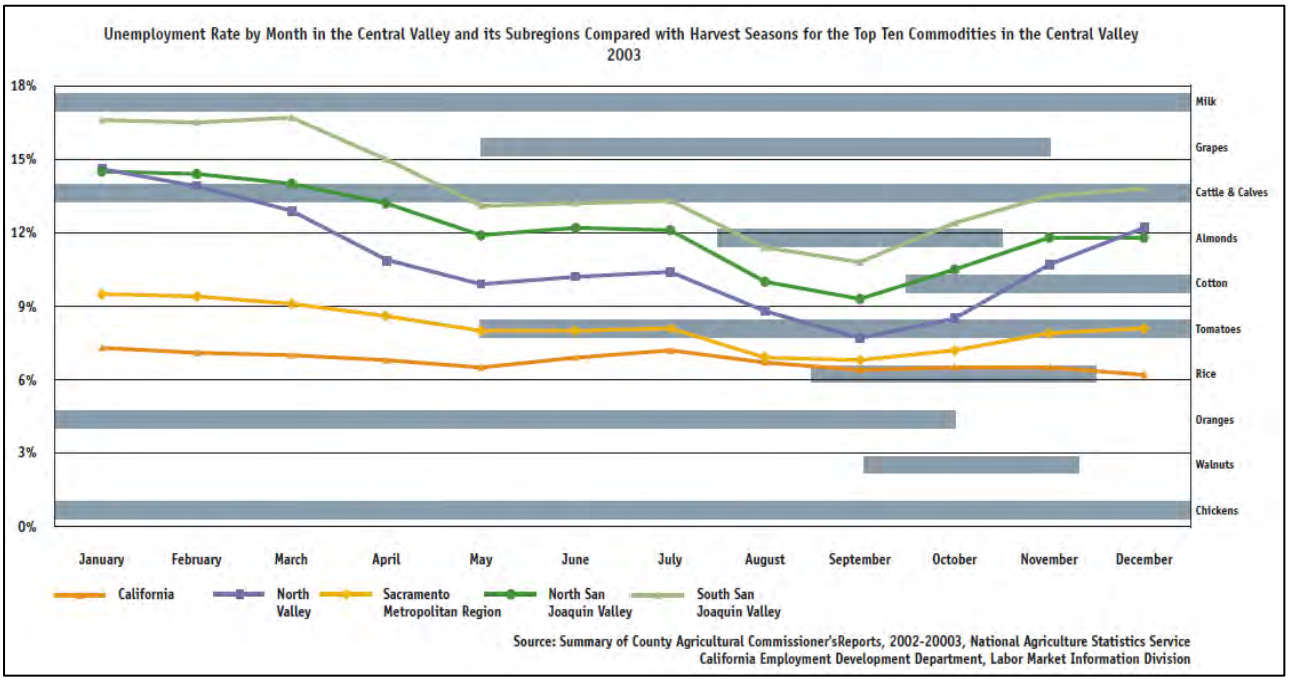

Figure 31: Unemployment rate by month in the Central Valley during the harvest seasons for the top ten agricultural commodities in the Central Valley.

(Source: Great Valley, 2005)[139]

Because of its particular sensitivity to changes in climate[140] and its dominant importance in the economy of the county, we focus primarily on agriculture, with only cursory treatment of other sectors at the end of Section 3.

3.2 Agriculture

Fresno is the Number One agricultural county not just in California, but in the entire United States, with a total value of production in 2008 of over $5.6 billion, an increase of more than 6% over the previous year.[141] According to the 2007 U.S. Census, the county had 1,636,224 acres of land in farms, nearly half of the county land area (48%).[142, 143] Of this, more than 67% was dedicated cropland and just over 28% was pastureland with the remaining 4% for other uses (Figure 31).[144, 145] The average size of a farm in 2007 was 269 acres, a decrease of 12% from 2002. Despite this decrease in the number of farms and in the total land in farms, the market value of products sold increased, with an average $613,476 in value produced per farm in 2007.

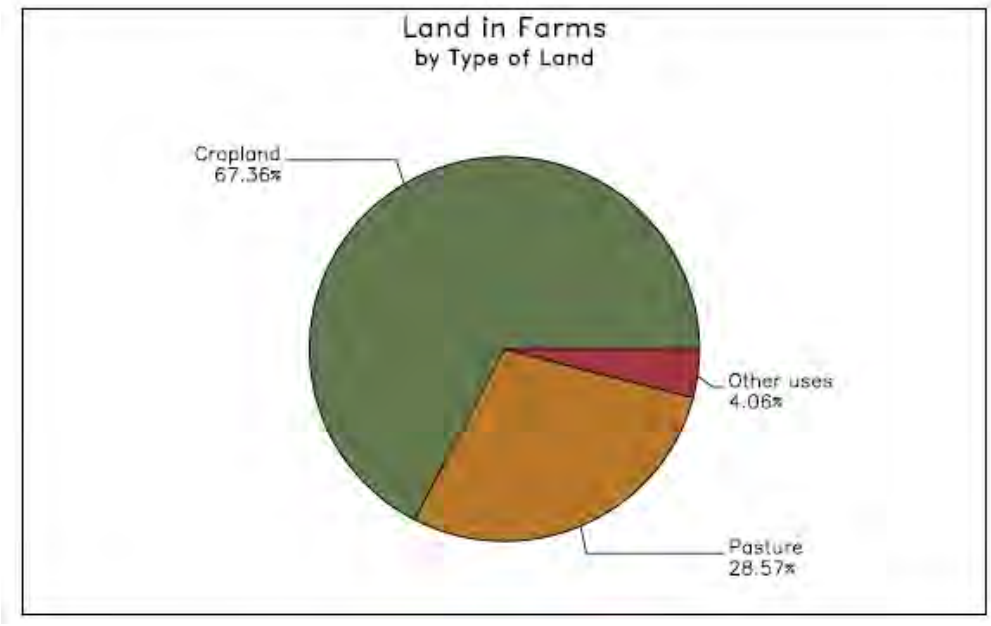

Figure 31: Proportion of land in farms in Fresno County

(Source: Census 2007, Fresno County Profile)[146]

Clearly, farming and agriculture-related businesses are dominant components of the local economy and are responsible for no less than one out of every three jobs.[147] Fresno's agriculture includes a majority of conventional and a growing number of organic farms. As of 2007, there were 61,159 acres in organic agricultural production, with 5,560 acres being converted for a total of 158 organic operations in the county.[148] While the list of major crops in the county is long (Table 4), the ten highest ranked crops by dollar amount in 2009 were grapes, tomatoes, poultry, almonds, cattle, milk, nectarines, oranges, peaches and garlic (Table 5).[149]

Table 4: Major Vegetable, Fruit, and Field Crops and Livestock Products

Type of Crop of Livestock	Major Crop Types and Livestock Products
Vegetables	asparagus, broccoli, celery, garlic, lettuce (lead, leaf, romaine), melons (cantaloupe, honeydew, water), onions, bell peppers, squash, tomatoes
Fruit	almonds, apples, apricots, sweet cherries, grapes (raisin, table, wine), kiwi, lemons, nectarines, oranges (navel, Valencia), peaches, (clingstone), pears, pistachio, plums
Field crops	barley, dry beans, cotton lint, cottonseed, sugar beets, oil crops
Livestock products	chicken, sheep, lambs, turkeys, wool, hogs, pigs, cattle, calves, honey

(Source: Fresno County Crop Report 2009)[150]

Table 5: Fresno County Leading Agriculture Production (in 2009 Dollars)

Crop	2009 Ranking	Value	2008 Ranking
Grapes	1	$667,638,000	1
Tomatoes	2	$614,736,000	5
Poultry	3	$504,509,000	3
Almonds	4	$500,940,000	2
Cattle, Calves	5	$310,882,000	6
Milk	6	$297,720,000	4
Nectarines	7	$187,044,000	10
Oranges	8	$173,521,000	8
Peaches	9	$171,606,000	7
Garlic	10	$150,791,000	9

(Source: Fresno County Crop Report 2009)[151]

3.2.1 Threats from Climate Change to Agriculture

Climate change poses a serious threat to agriculture for the State of California and Fresno County. Temperature increases observed statewide and globally have been partially masked in the past few decades by cooling from irrigation. But the aerial extent of irrigation is expected to stabilize, thus unable to mask further increases. Thus, temperature increases and other climatic changes pose serious threats to the leading economic sector of the county, including:

- higher temperatures, including extreme temperatures, can negatively affect crop growth during various stages of their development, as well as cattle and poultry health and reproduction;
- higher temperatures, especially in the main harvesting months, are also dangerous to agricultural workers (see Section 1);
- reduced water availability as a result of (a) the projected decrease in snowpack as more precipitation falls as rain than as snow and (b) higher temperatures leading to higher evaporation from reservoirs and soils resulting in reduced reservoir storage and generally drier conditions; any decrease in total precipitation as projected by the latest climate change projections for the state would only exacerbate these declines in water supplies;[152]
- more intense downpours can lead to fruit, vegetable and flower damage and more soil erosion;
- water demand by plants and animals (for drinking and cooling) will increase as temperatures increase;
- reduced number of chill hours (with relevant temperature thresholds varying by fruit crop);
- less-well understood effects of changing climate on crop pollination;
- lower productivity of rangelands for cattle; and
- increased risk of pest infestations and spread of invasive plant species.[153, 154]

One of the potential benefits of a warmer climate is that cold extremes and late winter and spring frosts – which can pose serious threats to sensitive crops – will continue to become less frequent (Figure 32).[155] Many crops also respond positively to elevated carbon dioxide under lower levels of warming, but this beneficial effect on growth and yields is limited quickly by higher levels of warming and water or other nutrient shortage.

Figure 32: Frost-sensitive crops such as cherries and oranges may benefit from the decreasing risk of late winter and spring frosts as the climate warms.

(Photo: USDA)

The county's agricultural sector exhibits existing sensitivity to two main types of climate-related extreme disturbances: changes in temperature and potentially reduced water availability. Both of these will manifest impacts in several ways. For example, temperature changes will lead to higher temperatures and longer and more frequent heat waves in the summer, but also lead to reduced chill hours in the winter. While spring frosts will become less frequent over time, they will still occur and potentially cause serious economic damage, especially if frosts were preceded by unseasonably warm temperatures that caused early blooming. For example, in 2006 Fresno County growers were impacted by cold and wet spring weather with an estimated $21 million in losses.[156] Increases in temperature during the winter and spring may also lead to increases in pests and disease for crops since the warmer winters allow insects and pathogens to survive and reproduce more frequently.[157]

Extreme temperatures are also difficult to handle for livestock. For example, during the 2006 drought, farmers had to contend with 21 days of over 100 degrees, including three days over 113 degrees. The state declared a heat emergency for Fresno County. By the time the heat wave was over, between 16,500 and 25,000 dairy cattle had died across the Central Valley, along with up to 700,000 poultry. Milk production was down 30 percent, with dairy losses alone estimated at over $80 million.[158] Federal/state disaster relief included $16 million for lost milk production. "Residual effects from loss of sales and resulting unemployment were considered to be three times the cost to the livestock industry."[159]

Fresno agriculture is heavily reliant on the snowpack melt from the Sierra Nevada Mountains, whether it comes from the Central Valley Water Project or the reservoirs fed by the San Joaquin and King Rivers. With climate change projected to decrease snowpack overall, the runoff providing water supply to agriculture and urban and industrial users may be reduced overall. While there may be more water available in the spring, less is projected to be available in the late summer and fall. With potentially decreasing precipitation and longer dry periods with

increased evaporation, groundwater recharge is also expected to be lower, although there is only limited research on groundwater changes due to a warmer climate to date. Below we briefly summarize specific threats to key crops and livestock in the county, given their importance among its agricultural commodities.

GRAPES

In 2007, grapes were the top crop in the county in terms of the number of acres (215,170)[160] and dollar value (over $667 million) produced. Fresno ranks as the top producer of grapes in the state and the country, as well as the top producer of tomatoes in the open with 109,758 acres. While grape varieties grown in the valley are adapted to high temperatures, unseasonably high temperatures at certain times in the year, can undermine the quantity that can be produced. For example, in January 2006, "Growers expressed concern about what effect the unseasonably warm temperatures and lack of chill hours will have on their crops, as many orchards and vineyards were pushing buds".[161]

NUT CROPS

Like stone fruit, nuts and almonds require a certain number of chill hours for the buds to set properly. With a value of over $500 million, almonds are the fourth highest value crop in Fresno County. Almonds and other nuts need a certain number of winter chill hours, which are projected to decrease as the climate warms further.[162] While chill requirements vary by variety, almonds require 100-500 chill hours and pistachios 600-1,500 hours.[163] The higher number of chill hours required for a crop, the greater the chance that the warming climate may restrict productive harvests. Moreover, almonds are particularly sensitive to nighttime warming in February (possibly because such a rise speeds up blooming, exposing trees to rains and flower disease; later warming will also make for a more uniform bloom across all varieties, increasing pollination success by bees).[164] Unlike row crops, perennial crops like almonds and nut trees are a major investment and the variety cannot be exchanged from one year to another. Therefore, the selection of varieties that require fewer chill hours, their placement, and other farming practices (e.g., irrigation method as almond trees require significant amounts of water) are critical considerations in adapting to long-term changes in regional climate.

FRUIT AND VEGETABLES

Fruit and vegetable crops will benefit from a longer growing season, but may be variously affected by increases in temperatures, especially extremely high temperatures, the general drying trend and related risk of water shortages, as well as higher flood risks in valleys, near rivers and streams. More heat-resistant varieties may be available, but vegetable crops grown in the Central Valley are already among the more heat-resistant. Other crops require long-enough periods of dormancy. Most varieties of peaches, for example, require between 400-800 chill hours, making those with higher requirements less viable in the long run. In addition, certain temperature ranges during particular months are critical for adequate development and ripening. Freestone peaches, for example, will benefit from winter warming – particularly at night – but be harmed by additional warming during the summer.[165] Thus, the projected warming between now and 2030 could result in a roughly 10% (statewide) loss in yields by 2030 of the Number One perennial crop in California (and one of the top ten crops in Fresno County), unless farmers adapt (e.g., by switching to less heat-sensitive varieties or assisting in pollination success).[166]

POULTRY

Poultry is the third highest valued agricultural commodity in the county, reported at over $500 million per year. Chickens and turkey are especially sensitive to rising high summer temperatures. In several of the last few summers, heat was a costly problem: The heat wave of summer 2006 caused over 700,000 poultry to die in the Central Valley. Then again, in July 2007, an extreme, prolonged heat wave caused another mass die-off of dairy cattle and poultry.[167] That same year (2007), "an estimated 50,000 turkeys, weighing up to 40 pounds each, died, which created a disposal issue. Zacky Farms was hit hardest, but other losses were incurred at various locations throughout the county. A local emergency was declared to legally dispose of these animals at the local landfill."[168] Adaptive measures will need to be taken to prevent such massive die-offs (and economic losses to poultry farmers) as climate change increases the risk of more frequent and more intense heat waves across the county. Such measures might include providing cooling mechanisms (shade, sufficient ventilation, air conditioning, etc.) or selecting even better heat-adapted varieties of turkeys and chickens. For farmers, this means higher production costs, and for consumer higher food prices.

CATTLE & DAIRY PRODUCTION

Cattle is a critically important component of the agricultural sector in Fresno, with annual sales valued at over $301 million in 2009, making it the fifth highest value agricultural commodity in the county.[169] Climate change poses direct threats to this industry through heat extremes and higher demands on water resources, but also indirectly through changes to the quantity and quality (and therefore price) of forage. Cattle are at heightened risk of mortality from increased temperatures and possible decreases in reproductive success. To avoid these risks, farmers can choose a variety of ways to keep cattle cool, ranging from manual hosing off to increased shading and air conditioning, although these adaptation options typically are labor intensive and/or require substantial economic resources (both for the initial investment and ongoing operating expenses).[170]

In general, fewer studies have examined the impacts of climate change on grassland species; moreover climate change impacts are complicated by pasture management practices.[171] Higher temperatures, lengthened growing season, the fertilization effect of carbon dioxide on grass species, invasives, and the amount and timing of winter rains are among the key factors influencing the quality and quantity of forage. Statewide modeling studies suggest rainfall-driven declines of forage between 5% and 40% by the middle of the century, with resulting profit declines in California from livestock between $8 and $62 million. Inland areas of the county are among the hardest hit.[172] In 2006, the cattle industry of Fresno experienced just such weather-related economic losses when high temperatures reduced reproduction and increased mortality of cattle, and when general drought conditions reduced the available grass on pasture land.[173]

Dairy was valued as the sixth highest agricultural commodity in Fresno in 2009 (dropping from 4th in 2008) at nearly $300 million.[174] High temperatures not only can reduce milk production, but can kill the cows during extended heat waves.[175] According to one dairy farmer, "When cows get too hot they don't eat very much, they don't breed as much and they don't produce as much milk."[176] To prevent overheating, adaptive measures must be taken to provide cooling for

the animals. During the 2006 heat wave dairy farmers in the Central Valley took measures to help cows cope with the heat by spraying them with water to cool them down. Farmers also installed fans to help cool workers and cows. The Local Hazard Mitigation Plan reports that Federal/state disaster relief provided $16 million for lost milk production to Central Valley counties after the 2006 heat wave.[177] However, resources to support this type of disaster relief may be limited as both communities and heat-sensitive industries compete for scarce funds.

3.2.2 Farmers' Vulnerability and Ability to Adapt

Farmers' ability to deal with these climatic changes depends on a number of factors. Their particular vulnerability is a function of their exposure to these climatic changes, their sensitivity to those changes, and their adaptive capacity. Key factors include:

- location (e.g., valley or hill country, exposure, soil types)
- types and diversity of crops grown and/or livestock raised
- current farming practices (e.g., soil and water conservation practices, organic/conventional farming) and willingness and ability to change these practices
- access to water resources, wells, and water rights
- access to native pollinators (particularly, native rather than European bees)
- financial resources to invest in technologies such as irrigation, cooling and farm equipment required for growing new/different crops
- dependence on income solely from farming vs. several income sources
- access to flood and drought insurance
- participation in farming cooperatives
- access to labor markets
- access to, and use of, climate-related information for advance planning (e.g., through extension service, web-based sources)
- market-, policy-related, or legal constraints on farming.

In general, smaller farmers with fewer financial, technological, and water resources, and farmers with fewer or less flexible response options, limited crop diversity, fewer risk sharing opportunities, and greater dependence on farm income tend to be less able to adapt to or recover from climate change stressors, making them more vulnerable to climate change.[178] At the same time, smaller farms may be focused on growing high-value crops, which gives them financial incentives and means to innovate and adapt. In 2007, 59% of farmers in the county owned 50 acres or less, thus could be considered relatively small farms. Just over 20% made up the larger farms with 180 acres or more (Figure 34).

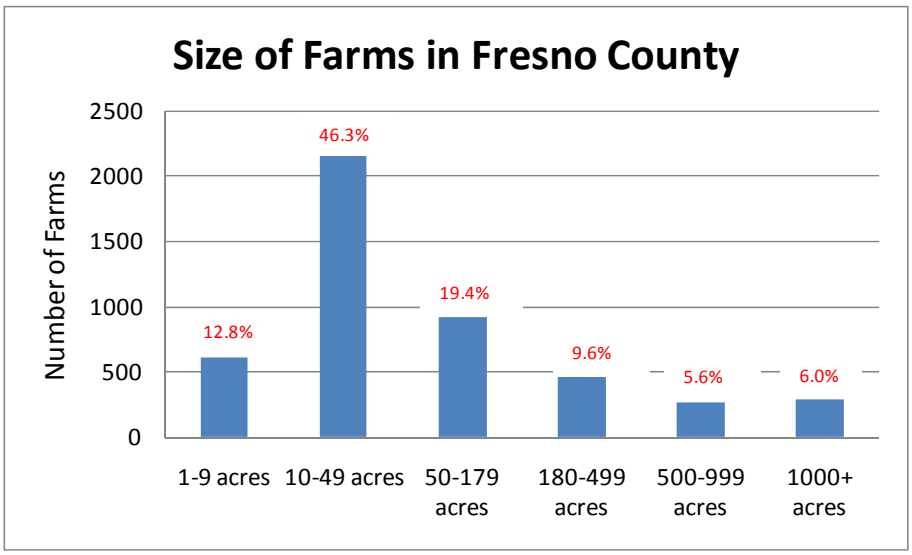

Figure 34: Number of farms by size in Fresno County 2007

(Source: U.S. Census, 2007, Fresno County Profile[179])

In summary, Fresno County as the leading agricultural County in the state and country is most vulnerable economically in its leading economic sector: agriculture. Much of the crops and commodities produced are already heat-tolerant ones, given the regional inland climate, thus further warming may exceed heat-tolerance for some crops and livestock. Given the dominance of the agricultural sector in terms of production value and employment, negative impacts on this industry will reverberate throughout the county and affect farmers, their employees (many of which, as Section 2 showed, are among the most vulnerable social groups), related industries, and consequently local government budgets. Thinking about adaptation in agriculture thus is not a luxury or task to be postponed to some future time, but is at the very heart of the county's economic vitality, and thus central to the implementation of the Valley Blueprint vision.

3.3 Service Industry

As mentioned above, the service industry is next to agriculture the most important employer in Fresno County. According to the California Department of Finance (DOF), "nonagricultural employment in Fresno County in February 2001 numbered 297,600 workers. Of that number, 77,700 persons were employed in the service industry. The service industry employs approximately 26 percent of the nonagricultural wage and salary employment in Fresno County."[180] The service industry comprises work in retail, accommodation, food and cleaning services, administration, health care, education, and so on. While these jobs may not be directly dependent on or sensitive to changes in climate, the existence of a viable economy in the service sector depends on the level of diversification and development of the economy as a whole. In Fresno, there presently is a very high reliance on agriculture and related industries, and only limited diversity of other industries. Consequently, when agriculture suffers, so does the rest of the county economy. Moreover, many, though not all, of the jobs in the service industry are in the low-income category, leaving those dependent on them in an economically vulnerable position.[181]

A limited number of service jobs are in the recreation and tourism sector. The county offers a variety of outdoor recreation opportunities (lakes for fishing, boating, swimming and water skiing; hiking trails, golfing, biking, hunting; skiing and snowmobiling in the mountains; and other outdoor sports activities). Many of these activities are dependent on environmental conditions (such as sufficient snow, comfortable outdoor temperatures, water temperatures required for preferred fish, absence of health risks such as fire, air pollution, and insects), and thus will be affected by climate change in direct and indirect ways.[182] As many of these activities take place on Federal land (1/3 of the county area is Federal), close collaboration on adaptation between local and Federal land managers will be critical. (For more details of climate change impacts on natural environments, see the report prepared for the natural systems workshop by the National Center for Conservation Science and Policy).[183]

Fresno also serves as a major gateway for Yosemite, Sequoia, and Kings Canyon National Parks. Yosemite received nearly 4 million visitors in 2009,[184] and those coming from Southern California typically arrive through Fresno (Highway 168) to enter the park. Services to support these visitors are thus a part of Fresno's service sector economy. To the extent, climate change alters the desirability of these tourism destinations for outside visitors, Fresno may experience some indirect impacts in this sector as well. However, issues like rising energy prices and their impact on transportation costs may be felt first and more severely, as visitors from far-away places may choose to recreate and go on vacation closer to home.

Section 4: Community Services, Infrastructure & Supporting Activities in Fresno County

4.1. Supporting Infrastructure and Services: An Introduction

In support of people's daily life, well-being, safety, travel and participation in Fresno County's economic activities, cities and the County provide a variety of infrastructure and community services. Many of them are susceptible to being affected by climate change, both directly and indirectly. First and foremost is the provision of the most essential resource for both urban and rural areas: water. Water quality and supply issues are already high on the public agenda, and climate change will assure that they remain there. In addition, we will discuss wastewater management, transportation, emergency preparedness and response systems, and energy. The Valley Blueprint recognizes the all-important conservation and management of ecosystems for the goods and services underlying much of Fresno County's economy and quality of life. We refer the reader to the natural systems adaptation workshop and resulting report.[185]

4.2 Water

Water management in California involves a complex mix of state and federal agencies, local, tribal and special district institutions, and private companies. Each has specific responsibilities around the three principle areas of water management: supply, quality (including wastewater) and flood control (Table 6).

Table 6: Entities involved in Various Aspects of Water Management in California

Agency (State or Federal) or Entity	Responsibility		
	Water Supply	Water Quality	Flood Control
Department of Water Resources	X		X
State Water Resources Control Board	X	X	
CALFED Bay-Delta Authority	X	X	X
California Public Utilities Commission	X	X	
Colorado River Board	X		
Department of Pesticide Regulation		X	
Department of Public Health		X	
Department of Toxic Substances Control		X	
Office of Environmental Health Hazard Assessment		X	
Bureau of Reclamation	X		X
Army Corps of Engineers	X		X
Environmental Protection Agency		X	
U.S. Geological Survey	X	X	
Tribal governments	X	X	X
Cities and counties	X	X	X
Special districts	X	X	X
Private water companies	X		

(Source: Adapted from LAO, 2008)[186]

One of the principal challenges Fresno will face in dealing with water management issues in the future is to foster effective collaboration, communication, and coordination among all these entities, given the absolute importance of water for the county economy and its people. Coordination is not just required across scales of governance, but across spheres of responsibility and across economic sectors within the county.

4.2.1 Water Supply

Sources of water for the county include groundwater (mainly Kings Groundwater Basin), State Water Project, Central Valley Water Project, and surface water from reservoirs sourced by the Kings and San Joaquin Rivers.[187] Surface water supplies are somewhat geographically divided with the Sierras (Kings and San Joaquin River watersheds) serving the eastern part of the

county, while the Sacramento-San Joaquin Delta and Shasta Reservoir serve the western part of the county.[188] In drought years, reliance on groundwater increases (due to lower supply of surface water), but groundwater and surface water sources are closely connected and both will be affected by a changing climate.

Many communities rely on diminishing supplies of groundwater, while others rely on surface water stored in reservoirs that comes from the rivers fed by runoff from the Sierra Nevada Mountains. The City of Fresno, for example, relies largely on groundwater and, according to the Fresno Department of Public Utilities, its water basin level has "dropped from less than 30 feet below the surface in 1930, to more than 128 feet below the surface in 2009" (Figure 35).[189] As the water table sinks lower due to overdraft (taking out more water than is being naturally recharged into the ground by rainfall), more electricity and deeper wells are required to pump up the water. In fact, during the 1987-1992 statewide drought, the city experienced groundwater level declines to such an extent that nearly a fifth of all wells had to be lowered, water system pressures during peak demand periods were significantly reduced, and minimum fire flows and domestic consumption needs were threatened.[190]

Figure 35: Excessive use of groundwater over time has led to groundwater basin depletion and substantial subsidence of land. This 1977 photo shows how many feet the land subsided as a result of groundwater withdrawal in the San Joaquin Valley from 1925 to 1977.

(Photo: USGS, 1977)

There are currently 255 water wells in the City of Fresno which cost approximately $9 million per year just for the electricity to run the well pumps. Approximately half of the county's population resides in the City of Fresno and with its population projected to increase substantially in the next few decades, water is one of the main challenges the city faces (along with the economy and jobs). Recognizing the costs of overpumping groundwater, the City has implemented a water recharge program by purchasing water from Millerton Lake and allowing it to percolate back into the ground to help recharge the depleted groundwater basin. Until 2004, the city relied entirely on groundwater, but now has a facility providing up to 15% of the potable water (during peak summer season) from surface water originating from snowmelt from the Sierra Nevada running off into the Kings and San Joaquin Rivers.[191, 192]

In addition to the county's use of depleting groundwater, agricultural producers rely on state water provided by the California Aqueduct (which comes through the western region of the

county) and from the Kings and San Joaquin Rivers (and connected reservoirs) that come from the Sierra Nevada Mountains.[193] These water sources are supplied by the meltwater from the snows falling over the Sierra Nevada Mountains.

Historical and recent experiences make clear that water supply shortages are already a serious problem for many regions in Fresno County. Most recently, in 2009, near the end of the multi-year drought, environmental needs for a federally listed endangered species, the Delta Smelt, led to extreme water restrictions in the Valley:

"For the west side, extremely dry conditions in Northern California and implementation of a series of environmental regulations and pumping restrictions in the Delta have created an unprecedented 0% allocation for CVP water users south of the Delta, which includes Fresno County-based districts such as Westlands, Panoche, and San Luis water districts and Tranquillity and James irrigation districts, and 17 other districts along the Valley's west side." [194]

Further restrictions ensued due to historic water rights to the waters of the San Joaquin River held by the Exchange Contractors, resulting in reduced surface water supplies also for the eastern Friant districts, including some in Fresno County. [195]

Under the projected climate changes shortages such as these are expected to become more acute. Climate change projections summarized above suggest that the county will experience a longer dry summer season, and generally drying conditions, especially from the middle of the century onward. In addition, climate change is projected to lead to a reduction in snowpack and melt earlier in the year. The region may also see fewer but more intense rainfall events.[196] Currently, there is insufficient infrastructure to harness any surplus of water during wet years.[197] Moreover, higher temperatures will increase evaporation from open water surfaces and soils, thus increasing the demand for water supplies (for irrigation) while groundwater, mountain snowmelt, and streamflow are expected to decline, especially when demand is highest. Furthermore, evaporation from irrigated soils can lead to damaging and costly problems with salinization (Figure 36).[198]

Figure 36: In hot climates such as the inland Mediterranean climate experienced in the Central Valley, irrigation of agricultural crops is commonplace. Salinization of irrigated soils – as a result of water evaporating while salts remain in the soil – can be an undesirable and costly side effect.

(Photo: USDA)

"[T]he concentration of salts in the soil and shallow ground water [thus] increases and may reach levels detrimental to plant growth. Shallow irrigation wells worsen the problem by recirculating the saline shallow ground water, thus accelerating the process. The only remedy for this problem is to provide subsurface drainage to remove the shallow saline ground water."[199] (See also Figure 37)[200]

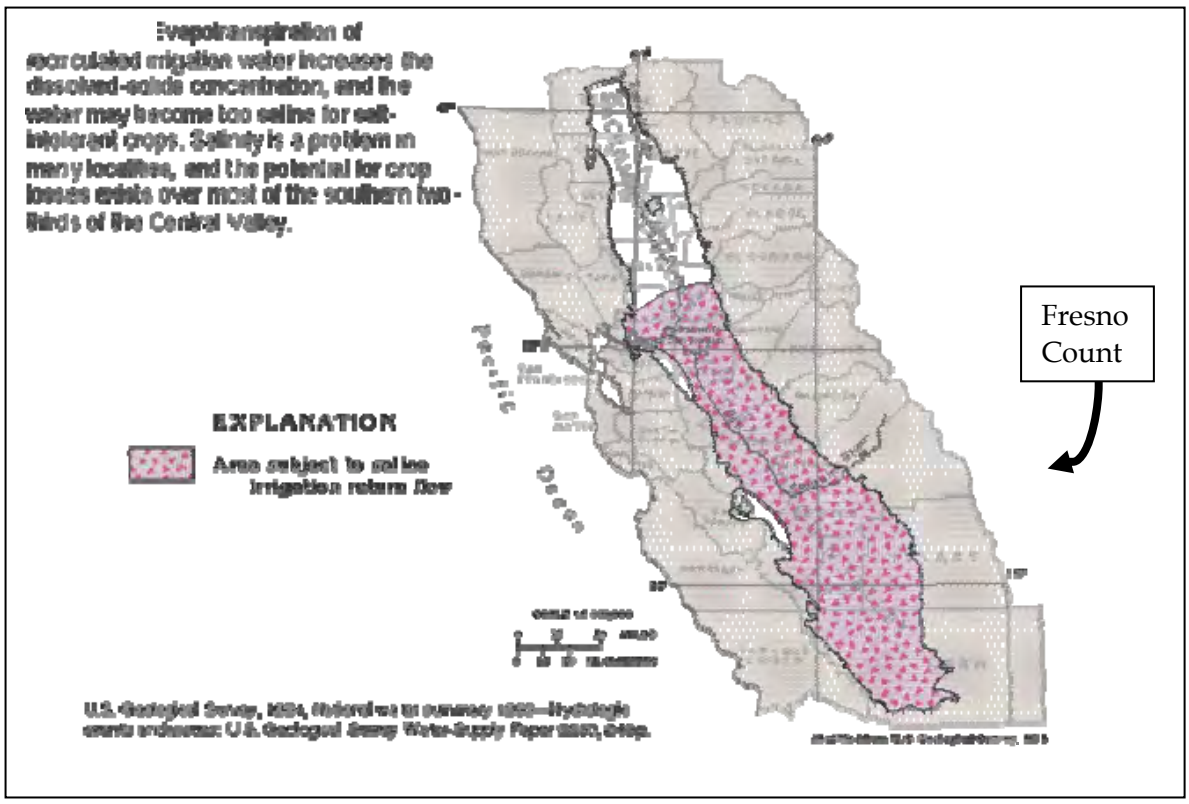

Figure 37: Map of Central Valley indicating areas that are susceptible to salinity problems from evapotranspiration and dissolved solids.

(Source: USGS, 1984, Fresno County added)[201]

Between now and 2050, Fresno County expects a doubling of its population (i.e., more urban and residential water users) and continued productivity and growth in agriculture (the primary water user).[202] Thus, even if climate change were not an issue, Fresno would face considerable challenges in meeting its water needs.

Clearly, the county is aware of the water shortage problems, especially in light of the growing demands from its growing population. For example, the City of Fresno households currently have one of the highest rates of water usage in the country. Up to 70% of the 294 gallons average used per household per day goes toward landscapes needs. This high usage is expected to decrease once the water metering program is implemented in 2013. Currently, households pay a flat fee of $23 per month regardless of how much water they use,[203] but these will be billed a metered rate by the year 2013.[204]

In addition to recognizing current water shortage problems, it would be consistent with and necessary for successful implementation of the Valley Blueprint, if Fresno County communities would consider managing water in light of dwindling supplies (especially the decline of Sierra Nevada snowpack) and the increasing energy demand for pumping groundwater up from ever-greater depths. Because the county's water system and economy depend so tightly on limited water supplies and require substantial energy to function, Fresno is highly exposed to the impacts of climate change and to those of the state's greenhouse gas reduction policies.

4.2.2 Wastewater and Storm Runoff

The second key aspect of water management is water quality maintenance. The above mentioned groundwater salinization is of principal concern here. Other sources of water quality contamination can stem from insufficiently treated sewage and wastewater (from urban, residential and industrial users), excessive use of chemical and other substances that enter streams, lakes, and – ultimately – the groundwater, as well as storm runoff.

All incorporated cities, towns, and special districts in Fresno County own and operate centralized wastewater collection and treatment systems. Industrial facilities not connected to such centralized systems must provide treatment of their wastewater. Residential water users in rural areas frequently are not served by centralized systems and instead use on-site septic systems. There are 362 permitted dischargers in Fresno County, not including individual residential septic systems.[205]

According to the County General Plan Update of 2000, "Most of the cities in Fresno County generally have adequate treatment capacity for the foreseeable future. However, Firebaugh and Sanger typically experience wastewater flows that meet or exceed current design capacities for their systems. Efforts are currently underway in both of these cities to upgrade facilities to accommodate anticipated flows."[206] As the County plan recognizes, wastewater treatment capacity needs to keep pace with the water use accompanying urban growth and economic development. Both are expected to increase substantially over the next few decades, even in the Valley Blueprint's "Preferred Growth Scenario" (B+) recently adopted by the County, compared to the "Current Trends Scenario" (A).[207] This is doubly supported as the stress on potable water will increase with climate change (both through increases in demand and reductions in effective supplies). Loss of usable water resources due to impingements on water quality is a risk Fresno County cannot afford to take.

Water quality impacts of climate change are generally less well understood at this time than water supply questions, but several climate-related factors can influence water quality:

- Temperature increases in streams and lakes can reduce the amount of dissolved oxygen, thus diminishing the quality of aquatic habitats;
- High or prolonged rainfall, especially when occurring simultaneously with meltwater runoff events, can overwhelm the capacity of sewers and sewage treatment plants, thus increasing the risk of untreated water entering surface and groundwater sources;
- Reduced runoff into surface water from fields and urban land surfaces can reduce the influx of toxic and other harmful (in)organic substances, thus potentially improve water quality;
- High runoff volumes after long dry periods can carry high concentrations of toxic and other (in)organic elements and thus lead to spikes in harmful substances in the water.

Projected temperature increases and fewer, but more intense rainfall events, as well as the potential for coinciding winter rainfall and earlier meltwater runoff suggests that there may be considerable risks to future water quality for the county. Typically during winter and spring months, river and stream flows in Fresno County are higher than during other months due to rainfall and snowmelt. These runoff events may come earlier and be even heavier in the future,

thus close monitoring of runoff trends will be required to assess the changing flooding and spill-over risk.

4.2.3 Flood Control

Currently, a complex system of flood control facilities operated by local, state and federal agencies is involved in the strategic management of reservoir storage and releases and the use of canals to reroute stormwater around urban areas in case of immanent risk of flooding.[208] If winter and spring runoff pulses increase in the future, while water storage for the long dry summer months becomes even more pressing, reservoir and flood managers will be increasingly hard-pressed to balance the costs, benefits, risks, and trade-offs between too little water when it's needed, and too much water, when it's not.

Regionally, flooding risk varies across the county. The western part of the county, which is mostly used for agriculture and grazing and generally sparsely populated, drains many streams off the eastern slope of the Coast Range toward the Fresno Slough on the valley floor. According to the 2000 Fresno County General Plan Update,

"Due to their large drainage areas, many small creeks are prone to high flows and contribute to flooding in the western area of the valley. Urban areas in western Fresno County that are subject to flooding include the cities of Coalinga, Huron, and Mendota. Major facilities such as the California Aqueduct and I-5 are also subject to flooding during large storm events and can sustain physical damage as a result. … Important wetland habitat in the Mendota Wildlife Management Area is also subject to flooding and may be adversely affected by sediments and naturally-occurring minerals carried by flood flows."[209]

In the central part of the county – the most urbanized and populated region – the major flood issues are associated with the San Joaquin and the Kings Rivers and their tributaries. Several smaller reservoirs and flood detention basins as well as three major dams have been built to control flows on these rivers, including Friant and Mendota Dams (San Joaquin) and Pine Flat Dam (Kings) (see also the Emergency section below). Numerous roads are subject to street flooding during heavy rains.[210] The County is well aware of its flood risks, yet again, may need to augment its planning efforts by monitoring changing flood risks over time, as well as consider the additional risks of bigger floods in some years as it permits more building and development in flood-prone areas over the coming years:

"The storage capacity at Millerton Lake (impounded by Friant Dam) is inadequate for full flood protection during wet years, and emergency releases have resulted in levee breaks and flooding along the San Joaquin River. … Between Gravelly Ford and the Chowchilla Bypass, the river is confined by a levee system. Erosion, seepage, and prolonged high water levels compromise levee integrity. Downstream of the Chowchilla Bypass, the river is not confined by levees and has limited capacity, resulting in uncontrolled flooding north into Madera County."[211]

Eastern Fresno County is characterized by smaller local watersheds draining to reservoirs upstream of Millerton and Pine Flat Lakes. Relatively low levels of population and urban development make flooding less of a risk at present, but care must be taken not to develop in floodplains as earlier runoff combined with winter and spring rains can overwhelm the streams,

thus increasing the flood risk in these areas.[212] Moreover, streamflows originating from this area contribute significantly to flooding potential on the valley floor.[213]

4.2.4 Drought

The recent multi-year drought (2007-2009) illustrates the enormous importance and potentially severe economic and social impacts that such "slow-onset" disasters can have (see additional examples in the section on economic sectors/agriculture in Section 2 above). According to the California Department of Water Resources, Fresno was one of the counties that submitted drought-related emergency proclamations in 2007-2009. "A common theme among the majority of the proclamations was related to agricultural water shortages. Additional impacts mentioned in the proclamations include the Fresno County unemployment food crisis" as well as urban water shortages and increased wildfire risk. "Bi-monthly food distributions were held for months in various cities and towns in Fresno County: and the City of Fresno, for example, mandated conservation measures and restricted outdoor residential water use.[214]

The Fresno County Office of Emergency Services (within the Public Health Department) provides links to the Center for Disease Control website, which has educational materials on how to respond to heat and cold waves, storms, flooding, wildfires, and other hazards. The County does not currently explore the implications of climate change, and an important opportunity exists here to update existing plans, and strategically consider and plan for the financial and social implications of more frequent weather-related disasters.

4.3 Emergency Preparation and Services

Well functioning emergency plans, preparedness, response services and careful recovery planning are critical for regional and community resilience.[215]

Table 7 lists a number of significant disasters that Fresno County has experienced in recent decades. Most of them are weather-related, though the list underestimates the actual occurrence of weather-related damages as droughts and extreme heat events are not included. Climate change is expected to lead to a decrease in late-spring freezes, but also an increase in the number of climate- and weather-related extreme events, such as wildfires, droughts, flooding and heat waves, thus increasing the demand for emergency services. Over time, this implies a need for increasing budgets or contingency planning to continue to be able to respond effectively.

Table 7: Significant Disasters in Fresno County since 1972

Hazard Type	Disaster #	Year	State Declaration	Federal Declaration	Location	Damage*
Freeze and Severe Weather Conditions	--	1972	4/17/72	--	Fresno County (and 16 other counties)	$111,517,260
Drought	--	1976	2/9/76	--	Fresno County (and 30 other counties)	$2,664,000,000
Rains Causing Agricultural Losses	--	1982	10/26/82	--	Fresno County (and 10 other counties)	$345,195,974
Winter Storms	DR-682	1982/ 1983	3/15/83	2/9/83	Fresno County (and 43 other counties)	$523,617,032
Coalinga Earthquake	DR-682	1983	5/02/83	5/3/83	Fresno County	No deaths 47 injuries $31,076,300
Storms	DR-758	1986	2/26/86	2/18/86	Fresno County (and 38 other counties)	13 deaths 67 injuries $407,538,904
Wildland Fires	--	1987	9/03/87	--	Fresno County (and 23 other counties)	3 deaths 76 injuries $18,000,000
Freeze	DR-894	1990	1/11/91	2/11/91	Fresno County (and 32 other counties)	$856,329,675
Late Winter Storms	DR-979	1992	1/21/93	1/15/93	Fresno County (and 23 other counties)	20 deaths 10 injuries $600,000,000
Severe Winter Storms	DR-1044	1995	1/17/95	1/13/95	Fresno County (and 44 other counties)	11 deaths $741,400,000
Late Winter Storms	DR-1046	1995	--	1/10/95	Fresno County (and all other counties except Del Norte)	17 deaths $1,100,000,000
January 1997 Floods	DR-1155	1997	1/5/97	1/4/97	Fresno County (and 46 other counties)	8 deaths $1,800,000,000
Severe Winter Storms and Flooding	DR-1203	1998	--	2/9/98	Fresno County (and 39 other counties)	17 deaths $550,000,000
Freeze	DR-1267	1998-1999	--	2/7/99	Fresno County (and 7 other counties)	--
Severe Freeze	DR-1689	2007	--	3/14/07	Fresno County (and 11 other counties)	$1,400,000,000

Source: California Governor's Office of Emergency Services, www.oes.ca.gov/
*Damage amount and deaths and injuries reflect totals for all impacted counties

4.3.1 Levee and Dam Failure

As discussed above in the context of water quality and storm water runoff management, climate change is projected to intensify the hydrological cycle and thus lead to an increase in intense downpours in California, even if the overall amount of precipitation changes little or decreases somewhat toward the end of the century.[216] There are three types of flooding that can result in Fresno County: localized (street flooding from large amounts of surface runoff) and riverine flooding (see Flooding section above), and dam failure. Several road areas in the county flood regularly and require regular flood signage in the roadways.[217]

The 2008 Fresno County Local Hazard Mitigation Plan (LHMP) notes that Fresno County's vulnerability to dam failure is high with a "highly likely" probability of a dam failing in the future.[218] Potentially significant numbers of people could be threatened if a dam were to fail, for example, the Big Dry Creek Dam threatens a population of 266,502 people, though it only hold a capacity of 30,200 acre feet of water. This compares with the Pine Flat Dam (on the Kings River), which has a much bigger capacity of one million acre feet at capacity. If a complete failure were to occur while at capacity it would threaten 143,678 people.[219] While all 23 dams in or upstream from the county "present a significant safety risk to downstream populations if one or more were to fail"[220], four in particular pose the greatest threat: Big Dry, Fancher Creek, Friant (which would result in inundation of significant portions of the City of Fresno), and Pine Flat. A catastrophic failure of any of these dams would likely result in loss of life and property.[221] "The potential magnitude of a dam failure depends on the time of year and the base flow of the river when the failure occurs. During the winter months, when the river flows are higher, the impact to the area would be much greater and evacuation times much less."[222] At the time of the 2000 general plan update for the County, comprehensive analysis of the potential for dam failure and downstream effects for upstream dams – Shaver Lake, Lake Thomas A. Edison, Huntington, and Florence, and Mammoth Pool Reservoir, Wishon, and Courtright Reservoir – had not been undertaken. But dam failure evacuation plans were under development for the 23 dams located within the county.[223]

Ensuring that dams and levees are maintained to meet safety standards as rainfall patterns and runoff change in the future, requires coordination among a significant number of public agencies and private land owners. There were 37 levees on private land across the county as of 2007 that were deaccredited, typically because the owner did not intend to seek certification/accreditation.[224] "Most of the levees in the County could not be certified in accordance with the [design, operation, maintenance plans, and engineering certification] requirements of 44 CFR 65.10 for the 100-year flood event. As a result, substantial areas formerly designated as "X" zones [i.e., areas determined to be outside the 100- and 500-year floodplains], or protected from a 100-year flood event by levees, have been remapped into flood hazard "A" zones [areas inundated by 100-year flooding, for which no base flood elevations have been established]. Preliminary estimates show that over 7,200 parcels in the Fresno County planning area are being remapped."[225] Especially along the Kings River, many levees did not meet the requirements to gain certification.[226]

4.3.2 Wildfire

Wildfires are a hazard of major concern in Fresno County, particularly in the mountainous regions in the eastern county, and some higher-elevation areas in the western Coast Range (Figure 38). The northern region along the San Joaquin Bluff is particularly susceptible to wildfire because of its steep slopes and vegetation. While the central portion of the county is not modeled for its fire hazard (due to the topography and fuel type requirements), this area still has some risk given the common brush vegetation and the hot dry summers, although these are more controllable than those that occur in the forest and steep terrain.[227] The state has identified several communities as being at particular risk to wildfire: Auberry, Big Creek, Big Sandy, Coalinga, Dinkey Creek, Dunlap, Friant, Hume, Lakeshore, Meadow Lakes, Miramonte, Piedra, Pinehurst, Prather, Shaver Lake, Squaw Valley, and Tollhouse.[228] Different parts of the county are under local, state, and federal fire protection jurisdiction, thus effective coordination and

joint fire hazard mitigation planning is required to adequately protect county residents and assets.[229]

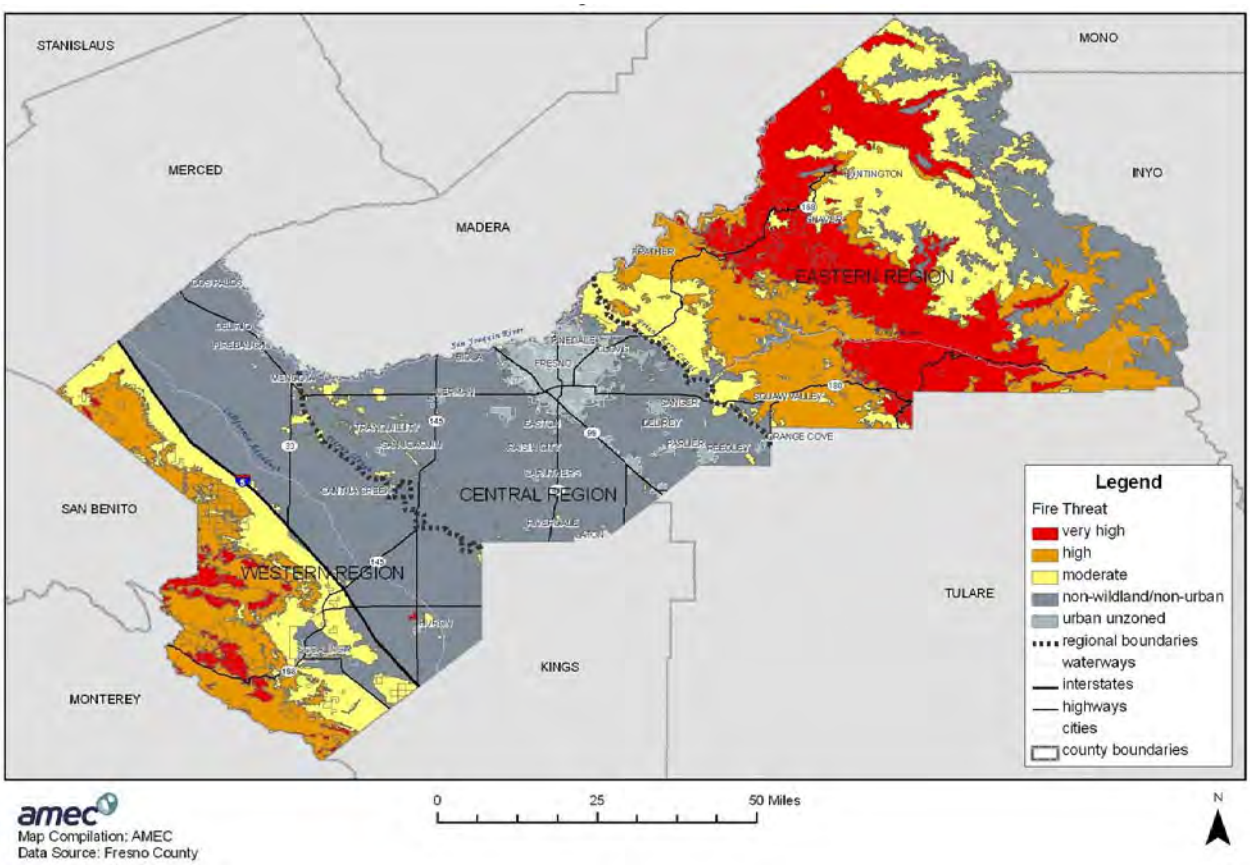

Figure 38: Map of fire hazard zones in Fresno County

(Source: Fresno County Multi-Hazard Mitigation Plan 2008, Figure 4.40[230])

Wildfire risks across the county will not only increase because of climatic changes (higher temperatures, general drying trend), but also where and when development increases at the wildland-urban. Second-home development in the foothills of the Sierra Nevada and the Coast Range are of particular concern in this regard. The risk of fires is greatest between June and October when humidity is lowest, vegetation is dry, and temperatures are hot. Not only do wildfires require a large amount of financial and human resources to fight, they also put people, important infrastructure and residential development, as well as species, ecosystems and the goods and services they supply (e.g., slow water infiltration, protection against soil erosion and landslides, water supply, timber, rangeland, aesthetic and recreational value of forest landscapes) at risk. "The loss to these natural resources would be significant."[231] The 1994 Big Creek Wildland Fire, for example, burned 9,000 acres of national forest, an area that is used for recreation and has many summer homes. This fire closed Highway 168 and Huntington Lake Road temporarily.[232] The 1989 Powerhouse Fire burned an estimated 21,000 acres and was

"devastating to the watershed, wildlife, and residents."[233] Secondary hazards from wildfires arise to people from smoke, as air quality is temporarily but significantly diminished. People with preexisting pulmonary challenges are particularly susceptible to additional health complications.

Of particular concern in water-scarce Fresno County – especially during already dry years – are the enormous water resources required to fight fires (see also Water Supply and Drought sections above)(Figure 39).

Figure 39: Fire fighting consumes enormous financial, human, and water resources. During already dry periods, when fire risk is highest, potentially difficult tradeoffs have to be made between water for human and agricultural uses versus fighting fires.

(Photo: US Navy)

4.3.3 Landslides

Landslides often follow heavy rains, especially in areas previously affected by wildfires and in mountainous terrain where soil is exposed to heavy rains. Given that both wildfires and the severity of heavy rain events may increase with climate change, landslide risks may also increase (Figure 40**Error! Reference source not found.**). Currently the highest risks for landslides are in the western part of the county, in the coastal range, where runoff from the region's many streams can be high, but fortunately population density and urban development is low.

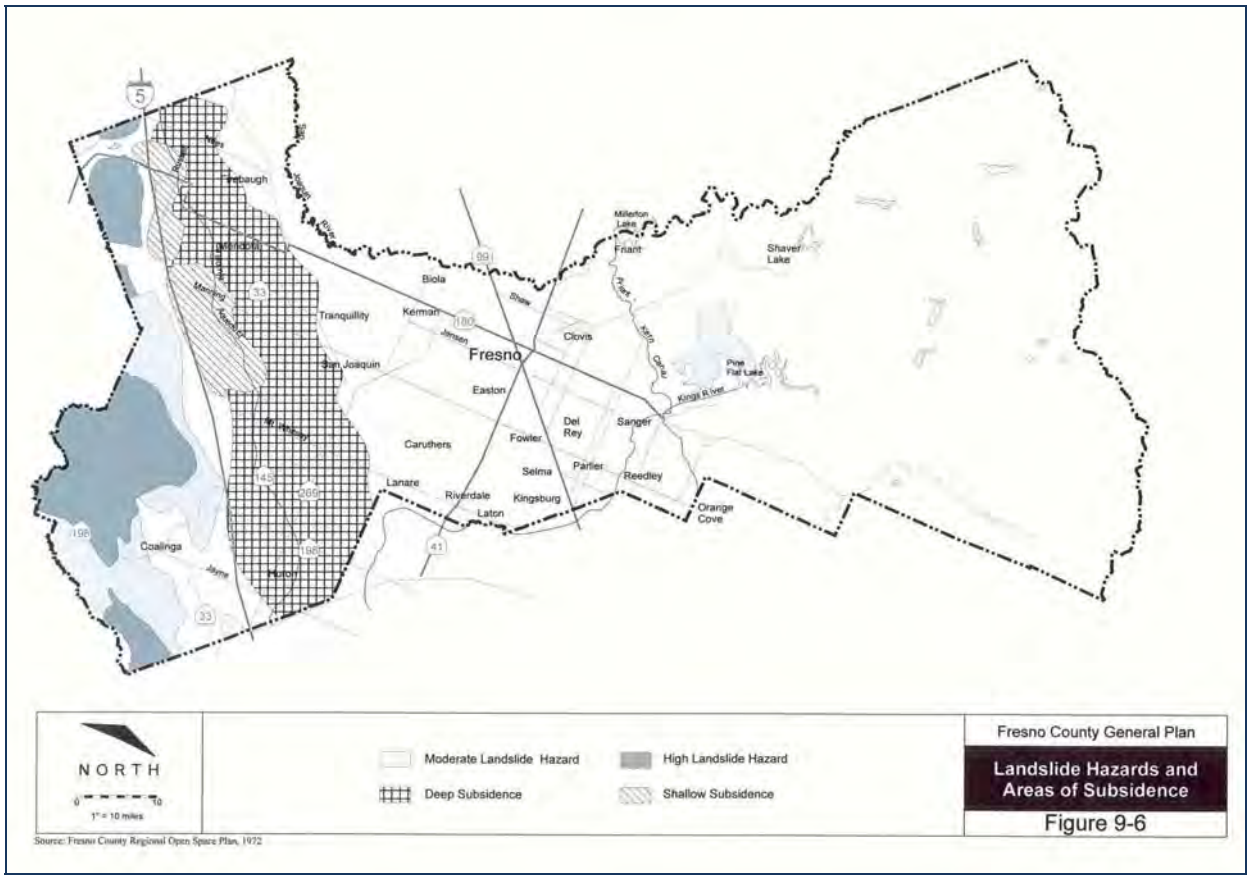

Figure 40: Landslide hazards and areas of subsidence in Fresno County

(Source: Fresno County General Plan Update, 2000, Background Document, Figure 9-6)

Again, careful monitoring of changing climatic patterns, cautious soil management, and care in development of high-risk landslide areas (e.g., housing, roads and other infrastructure) are relevant adaptive measures.

4.4 Transportation Infrastructure

The main transportation infrastructure of the county – its roads, airport, and railway – is in various ways susceptible to the impacts from climate change. The major transportation arteries to, from, and within the county include Highway 99 and Interstate 5 running north-south and several smaller routes running east-west. CalTrans District 6 is in charge of maintaining this infrastructure. Railways run through the county, with one Amtrak stop in the City of Fresno. The county has a number of airports including the Fresno Yosemite International Airport located on the east side of the city, an executive airport on the west side of the city, the New Coalinga Municipal Airport, and Harris Ranch Airport. In terms of public transportation, the Fresno Area Express covers Clovis, Fresno City, Pinedale, Calwa, and Malaga, but there are few options for more rural regions of the county.[234]

Transportation routes in the county are exposed to several climate related risks, including:

- heat extremes,
- flooding,
- wildfire, and
- associated problems with soil erosion, sedimentation, and landslides (Figure41).

Figure 41: Road damage after flooding, wildfire or landslides are just some of the risks from climate change to transportation infrastructure.

(Photo: FEMA)

Increased severity of winter and spring storms – combined with earlier runoff from the Sierra Mountains – could increase flooding of important transportation routes during intense rainfall and runoff events, including river and stream flooding (see Flood Control section above). Very wet years in addition could result in risk of dam failure at reservoirs. The main transportation routes in the valley region are at greatest risk, given their location downstream of reservoirs or adjacent to the county's rivers. Increased severity of heat extremes can damage existing roadways and railways (e.g. by increases in so-called "blowups" -- sudden cracking and tilting up of pavement slabs).[235] In the past wildfires have led to closures of important evacuation routes (e.g., Highway 168 in the Big Creek Wildland fire in 1994[236]) and climate change is projected to result in more fires in the region (with resulting higher costs for emergency repairs). Flood-related and post-fire soil erosion, sedimentation, and landslides can damage roadways and other infrastructure, and result in increased maintenance costs and traffic disruptions due to damage and repair.[237]

Good maintenance of road infrastructure is thus integral to, and essential for, the county's ability to provide emergency services to its residents and is at the heart of maintaining the infrastructure that supports a vibrant economy. Failure to monitor, maintain, and adapt transportation infrastructure will undermine the preparedness and ability to respond effectively to emergencies. These adaptations can be built into existing planning efforts and are most cost-effectively implemented when road repairs, maintenance or new construction is undertaken. Thus as Fresno County implements its Valley Blueprint, and special efforts like the City of Fresno's "Fresno Green" plan; realization of the smart growth initiative in Fresno – the

Southeast Growth Area (SEGA); or implementing transportation planning that is sensitive to the needs of disadvantaged groups such as non-white, low-income, elderly and disabled populations, taking into account future climate-related risks to ensure the long-term viability of its transportation infrastructure is good precautionary, integrated planning for sustainability.[238,239]

4.5 Energy

Given Fresno County's particular inland Mediterranean climate, with its very hot summers and cool winters, residents rely heavily on energy to maintain comfortable indoor temperatures. Moreover, agriculture and related industries are major consumers of the electricity used in the state. Together, farmers and food processors consume a total of 6% of the state's electricity.[240] Currently, the county's energy comes from natural gas, coal, nuclear, hydro and other renewable sources. There are several ways in which climate change will impact both the production of energy and the demand for energy. In short: Demands on energy supply will increase while energy supply sources will be stressed by climate change.[241]

For example, two of the major power plants from which the county draws its power are located on the coast (Moss Landing and Diablo Canyon). While inland Fresno will not be directly exposed to the impacts of a rising sea level, both these coastal power plants are susceptible to sea-level rise-related risks such as flooding and coastal erosion in the future, unless they are increasingly shored up against the forces of the sea. Moreover, there are proposals on the table right now to put more power plants in areas at risk of sea-level rise, such as in the Sacramento-Delta region.[242] In addition, snowmelt that feeds the reservoirs behind dams to create hydroelectric power is projected to decrease from climate change and shift in timing (see the Climate Change and the Water Supply sections above). According to a recent study undertaken for the State, high elevation hydropower generation clearly is expected to be impacted by climate change: "The ability to meet peak historical power demands in the summer months would remain basically unaltered. However, an increase in the occurrence of heat waves especially later in the summer period (September) would increase peak power demand at times when these systems might not be at peak power capacity unless operating strategies are modified."[243] In 2009, Fresno saw a decline in hydropower due to the prolonged drought, compensated for by the new Midway power plant about 15 miles southwest of Mendota in western Fresno County.[244] While supplying much needed energy, the natural gas-fueled plant emits heat-trapping greenhouse gases that cause global warming. In addition to needed water management changes, ratepayers may need to pay more for purchasing energy at peak demand times from another source.[245]

Another recent study of household energy consumption in California, considering climate change and population growth scenarios, found that the number of hot days (>87 °F) per year would increase significantly while the number of cool and cold days (< 77 °F) would decrease. This change is projected to lead a net increase in household electricity consumption in Fresno by 21-40% around 2040 and even more after that from the additional impacts of climate change (i.e., due to the increase in extreme heat days) (Figure 42).[246]

This can easily translate into higher household expenditures, if energy prices soar during peak demand times, and adequate adaptive measures (e.g., shade around the home, insulation, light-

colored roofs) are not taken.[247] Poorer residents will be hit harder by these increases than wealthier ones.

To help the more vulnerable populations, the County already provides a Home Energy Assistance/Emergency Crisis Program to assist low-income residents.[248] Climate change impacts on extreme summer temperatures are likely to increase the demand for and reliance on this program, especially if the number of poor and low-income families does not decrease in the future. This means, the county will need to increase the budget allocation for this program to meet increasing needs in the future. In addition, those most in need of such assistance – the poorest, those unemployed, or undocumented workers – may not be able to obtain County assistance because the program requires applicants to have a valid social security card, ID, and income verification.

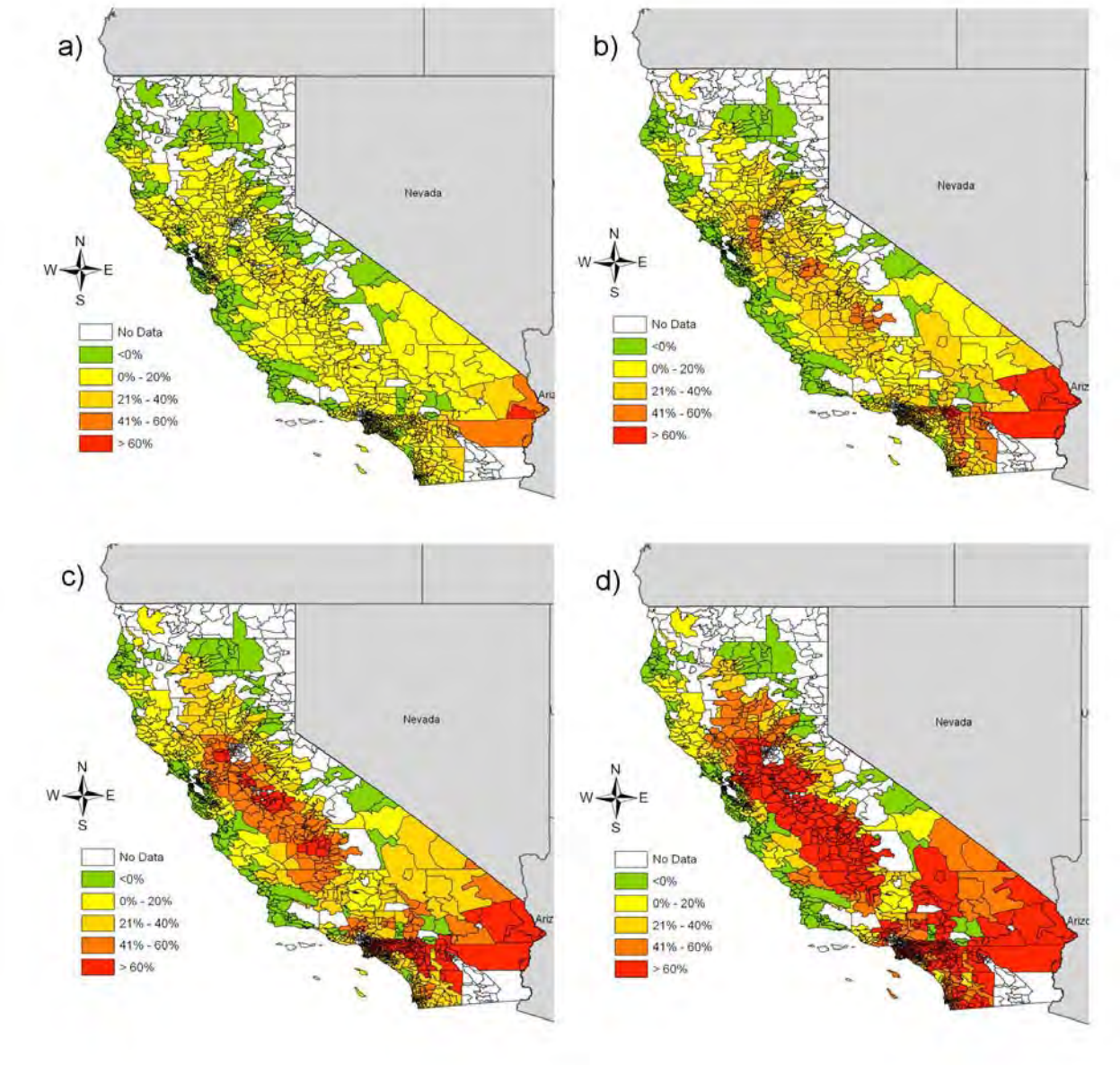

Figure 42: Simulated increase in household electricity consumption by ZIP code for the periods 2020–2039 (a), 2040–2059 (b), 2060–2079 (c), and 2080–2099 (d), in percent over 1980–1999 simulated consumption.

(Source: Auffhammer, 2009, p.19[249])

Both the county's Valley Blueprint and the City of Fresno's "Green Strategy" lay a foundation for building a more sustainable region and city, including using energy and other resources more efficiently.[250] This goal illustrates perfectly how sustainability, energy, and climate adaptation strategies go hand in hand, and in fact, can be harmonized to meet mutually enhancing objectives: greater energy security, fewer greenhouse gas emissions, and better

protection against the negative impacts of climate change. The adopted preferable growth scenario for the county envisions a 5.8% reduction in household-related energy emissions compared to the unrestricted development scenario, most of which will come from more efficient use of energy in heating, cooling, and appliances. Conservation measures may also be needed to meet the desired goal. The city is keenly interested in fostering a "green technologies" industry in the region to meet these growing needs by businesses and households, and indeed, there are signs that such an industry is beginning to establish in Fresno. According to a 2009 study, The San Joaquin Valley (which includes Fresno County) has the highest concentration of jobs in the wind energy sector in California, as well as high concentrations in clean fuel production.[251]

Section 5: Conclusions

Climate change will impact Fresno in a variety of ways, some potentially severe, with direct impacts on its people, its all-important agricultural sector (and related economic activity), its supporting infrastructure and services, as well as the natural environment on which much of the county's economy, rural character, and quality of life depends. The discussion in Section 2 (Communities), 3 (Economic Sectors) and 4 (Infrastructure and Community Services) have detailed, to the extent available, current vulnerabilities to weather- and climate-related changes and extreme events in Fresno, and how climate change may exacerbate or change them in the decades ahead. The impacts to these sectors will differ based on current and future vulnerabilities to weather- and climate-related changes and extreme events in Fresno County. The most critical vulnerabilities identified in this report include those associated with populations that are highly exposed and sensitive to additional environmental stresses and who have low adaptive capacity. In addition, the agriculture-dependent economy, and the necessary supporting infrastructure, are of particular concern.

In some instances significant social vulnerabilities, particularly among the poor, the elderly, infants, socially and culturally isolated individuals, and outdoor workers, who already do and – short of concerted intervention – will experience the greatest exposure, the highest sensitivity and/or the lowest adaptive capacity in the face of climate change impacts. The singularly most vulnerable portion of Fresno County's population is the low-income, Latino/Hispanic population, especially those also employed in the most vulnerable economic sector: agriculture. This population is predominantly located in the western and central part of the county (incidentally, the hottest, most air-polluted part). Diminished public health and limited access to health care and other social services can aggravate their vulnerabilities.

The county's leading economic sector – agriculture and closely associated industries – is the most vulnerable to climate change due to its dependence on sufficient water resources, particular temperature regimes for crops and livestock, and the absence of extreme events (e.g., droughts or floods). Smaller farmers in particular, and those with less diverse crop and livestock systems, and limited resources to invest in adaptive technologies will be most vulnerable to climate change in the future.

Crucial supporting infrastructure and services will experience greater demands or challenges as climate change-related risks grow, including for already scarce water supplies, emergency preparedness, response and recovery services, as well as transportation and energy services and infrastructure. Water cuts across all of these: As runoff of mountain snowpack comes earlier in the year, potentially coinciding with winter rains, while water storage for the long dry summer months becomes even more pressing, water managers will be increasingly hard-pressed to balance the costs, benefits, and risks between too little water when it is most needed, and too much water, when it is not.

Clearly, the county faces growing challenges that can be surmounted but only with timely and adequate planning and preparation. While difficult choices will need to be made, city and county governments are in the advantageous position of beginning their adaptation efforts early.[252] They can integrate many precautionary adaptive measures into their ongoing efforts to implement already existing plans, such as the Valley Blueprint, Fresno Green and other local measures. Many of these social, economic, institutional, educational, and infrastructure

measures can be implemented on regular maintenance, upgrading, planning, and budgeting cycles, and bring benefits to the County's residents, particularly its disadvantaged groups, its quality of life and natural environment, its fiscal situation and its economy overall. Thus, developing adaptation plans and implement agreed-upon measures is directly in support of Fresno County achieving its vision of a vibrant, prosperous and sustainable future.

Appendix A:

Constructing a Social Vulnerability Index with Factor Weighting

The Social Vulnerability Index (SoVI) is a well-established index method applied in natural disaster research to provide an objective snapshot of relative social vulnerability for a specified region. The social vulnerability index (SoVI) uses 32 variables of Census data to capture generic indicators of sensitivity, adaptive capacity, and social exposure. These variables are statistically integrated to create a single vulnerability score for a given census unit (census tract, block group, county, etc, depending on research needs and data availability). The standard deviations of the resulting scores are displayed visually using GIS mapping tools that can show patterns of how and where vulnerability differs within a given region. The following provides a summary of steps used to produce the map (for a more detailed description of methods, refer to 'The SoVI Recipe', as described on the Hazards & Vulnerability Research Institute website: http://webra.cas.sc.edu/hvri/docs/SoVIRecipe.pdf).

In the study of Fresno County, the analysis was conducted for a single county using US Census tract-level data. It is important to note that this analysis is based on relative assessment, meaning that there is a given high and low score within the county itself. If the analysis were conducted with a broader geographic scope, such as for the whole country, the county would show less overall vulnerability compared to many other places in the country (e.g. see http://webra.cas.sc.edu/hvri/products/sovi_32.aspx). The purpose of the analysis was to create a first snapshot to be able to identify possible areas that are especially vulnerable within the county itself.

The 32 variables collected for this study came from the US Census (Data Ferret *beta* database) from the year 2000. Census data for 2010 were not yet available at the time of this analysis. Principal Components Analysis (PCA) was conducted on the normalized data, resulting in a set of components (factors). Each factor is 'composed' of a set of one or more variables that highly correlate to it (Table 1). Following the Cutter et al. (2003) method precisely, the score for each factor adjusted by its sign to account for direction to which it relates to vulnerability (e.g. high income indicates low vulnerability and the score would need to be adjusted accordingly). At this point in the SoVI method, adjusted factor scores are then summed to create a cumulative vulnerability score.

The analysis we conducted for Fresno County, however, diverted slightly from Cutter et al. (2003) method by applying a simple weight scheme. When conducting the analysis using the SoVI method without weighting, we found the index scores differed from what we expected based on qualitatively assessing the maps of individual variables. The SoVI method does not use any weighting of the factor scores when adding them. This avoids the problem of subjectively determining the weighting -- among other challenges as discussed in Schmidtlein et al. (2008) and Rygel et al. (2006). Here we found Fresno's dataset exhibited a circumstance, as described below, which justified the need for a simple weighting scheme.

Individual factor scores were multiplied by the corresponding amount of variation they explained in the dataset (see Table 1). Fourteen of the variables were highly correlated to Factor 1, which was the largest contributor to vulnerability for this county. This factor explains 35% of the variation within the dataset analyzed, whereas Factors 1-7 together explain 77% of the variation in the dataset. As such, the high number of variables representing Factor 1 and the fact that it explains such a high proportion of the variation in the dataset are important attributes of the data that would be lost if we did not weight the factor scores. Therefore, by weighting each factor score by the proportion of variation explained (35% for Factor 1, 15% for Factor 2, etc.), the resulting sum vulnerability index score reflects the higher importance of Factor 1's score compared to the other factors. With no weighting applied, the index scores would have been a reflection of Factor 1, which represents 14 variables and explaining over one third of the variation in the dataset, as being of equal importance to Factor 7, which represents one variable (nursing home residents) and explains less than 4% of the variation in the dataset. The table shows which variables were most highly correlated to each factor (Dominant variables) and the degree to which each factor explains the variation in the dataset (Percent variance explained).

Table: SoVI Factor Analysis of dominant variables in Fresno

Factor	Name (representing dominant variables)	Dominant variables	Percent variance explained
1	**Socio-economic status**	• Population over 25 not graduated from high school • % Hispanic/Latino • % population living below federal poverty • % of eligible population unemployed • % renters • % population that does not speak English fluently • % employed in agricultural industry • Median age • Median rent • Proportion of population earning >$100K/year • # physicians • Per capita income • % population employed in service industry • % civilian labor force participation	35.5
2	**Housing and agriculture/urban**	• % urban land • Housing density • % females in labor force • % mobile homes • Land designated as rural farm	15.6
3	**Age**	• % receiving social security • % population 65+years • # persons per household • % population <5 years	9.2
4	**Employment and race**	• % employed in transportation industry • % Native American population	5.5
5	**Race**	• % Asian population • % African American population	4.9
6	**Sex and immigration**	• % female as head of household • % female in population • % immigrated within last decade	3.6
7	**Nursing home residents**	• Nursing home resident population	3.4

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Photo Credits

Figure #	Photo	Source
n/a	Fresno City Gates	David Jordan, Wikimedia
15	Flooding in Fresno County	Fresno County, OES website
17	Farm workers in field	Holger Hobbs, Wikimedia Commons
29	Farm worker drinking water	Rani McClean
23	Wildfire	FEMA
42	Cherries	USDA (Photo: k6012-20)
35	Subsidence in Central Valley	USGS, 1977
49	Soil salinization	USDA
57	Fighting wildfire by airplane	US Navy
59	Road damage from flooding	FEMA

Appendix B:

Integrating Smart Growth and Adaptation Strategies

Blue Print Strategies	Related Climate Actions from CSU-Fresno Study (Harmsen et al.)	Mitigation Benefit	Adaptation Benefit	Additional comments on enhancing or supporting Smart Growth and Climate Actions to better meet adaptation goals
1. Create a range of housing opportunities and choices • Set regional goals • Educate communities about affordable housing • Balance the geographic distribution of affordable housing • Provide incentives for affordable housing		• Fewer VMT, thus fewer transportation-related GHG emissions, if housing density is increased and/or distance between work and home is decreased	• Transportation-and housing related expenses are decreased, thus improving the financial situation of low(er) income households	• Affordable housing built with high levels of insulation, windows with good insulating values, and passive solar design elements provides better protection from heat.
2. Create walkable and bikeable neighborhoods • Encourage development standards that promote fully accessible neighborhoods and safe movement • Coordinate the location of school sites • Coordinate commercial centers • Provide access to healthcare, social services,	• Higher density, mixed use and accessible neighborhoods • Improve public transit systems (including, increase convenience and flexibility) • Encourage smart growth • Promote alternative	• Fewer transportation-related emissions of greenhouse gases and other air pollutants.	• Walking and biking increase overall health of individuals, which decreases sensitivity to heat-related health impacts. • If streets are not shaded, walking and biking can increase exposure to heat extremes. • Outdoor activity and encounters can increase the sense of community and social capital useful	• Walking and biking is more likely to occur if it is encouraged in schools and through targeted outreach campaigns, incl. efforts to increase overall sense of neighborhood and traffic safety.

child care, elder care, and other family support services • Create, preserve, and provide access to cultural amenities • Create safe routes • Create healthy forms of transportation	transportation infrastructure • Greening schools		for adaptation. • Fewer air pollutants reduce risk of pulmonary disease.	
3. Encourage community and stakeholder collaboration • Develop a shared vision • Formulate creative solutions • Work together	• Reaching out and being reachable • Networking and collaboration (city staff and officials)	• Improves information exchange, social learning, creates a sense of community, and builds social capital needed for mitigation.	• Improves information exchange, social learning, creates a sense of community, and builds social capital needed for adaptation.	• Collaboration needs institutional and appropriate financial support. • Leadership can be critical to initiate and sustain efforts.
4. Foster distinctive, attractive communities with a strong sense of place • Enhance existing communities • Create new centers • Encourage creativity • Address the unique needs of diverse population groups • Foster peace of mind • Build creative communities	• Living showcases of sustainability	• Positive examples provide models that others want to replicate, thus foster quicker social change.	• Collaboration, common goals, visions, engaging in creative activities, working together builds social capital, trust, and adaptive capacity. • Positive examples provide models that others want to replicate, thus foster quicker social change.	• Cultural events, as well as ongoing programs, for and by all generations and community segments are important to create sense of lively, engaging community.
5. Make development decisions predictable, fair and cost effective • Make smart growth profitable for the private sector and developers • Expedite the approval		• Greater resources for change through partnerships.	• Greater equity and fairness increase adaptive capacity of the whole community, not just of those better off. • Greater resources for change through	• Transparent governance and opportunities for meaningful stakeholder engagement in decision processes build adaptive capacity.

process, listening to the "time is money" mantra • Balance interests fairly			partnerships.	
6. Mix land uses • Live, work and play in close proximity • Provide for a more diverse community • Enhance the vitality and security of the community • Revitalize the community in which we live	• Higher density, mixed use and accessible neighborhoods • Greening schools • Living showcases of sustainability	• Fewer transportation-related GHG emissions and other air pollutants.	• Diversity can build adaptive capacity. • Vital, integrated communities have greater social capital, which builds adaptive capacity.	• Effective community organizers and leaders are needed to help integration across diverse communities.
7. Preserve farmland, open space, natural beauty and critical environmental areas • Encourage sustainable agriculture • Identify the "must save" lands • Invest in preserving critical lands • Ensure that residents can easily access recreational areas • Develop in a sensitive manner • Plan for future water needs	• Living showcases of sustainability	• Certain farming practices reduce agriculture-related GHG emissions (from direct fuel use, animal waste, and fertilizer use). • Some crops and farming practices enhance the uptake of carbon in the soil. • Long-lived crops and reforestation enhance carbon uptake in biomass and soil.	• Efforts to preserve habitat, and connecting corridors between habitats, improve the chances for natural species adaptation. • Farmland preservation enhances the options for farmers to adapt to climate change impacts (e.g., moving to better-suited land for particular crops). • Open space preservation increases water retention by reducing run-off, flooding, and fostering groundwater recharge; this reduces exposure to flooding and drought risks. • Local food security may be enhanced by protecting the local land	• Regional collaboration across county (and even state) boundaries is often necessary for adaptive habitat planning. • Pressures to convert agricultural land to other uses arise from drivers often beyond local control, thus successful protection of agricultural land often requires regional, state, and national collaboration. • Open space and natural beauty enhance opportunities for a different economies, thus fostering diverse economic activities (e.g., ecotourism) can improve the overall local/regional adaptive capacity.

			to grow food.	
8. Provide a variety of transportation choices • Connectivity between centers and to other regions • Congestion relief • Choices for moving people and goods • Concurrency with new development • Ensure access to key economic assets • Provide connectivity to global markets	• Online information center regarding alternative transportation choices • Improve public transit systems (including, increase convenience and flexibility) • Sustainable urban transportation planning • Bus shelters • Parking area tree cover • Tree cover of pedestrian areas • EV charging facilities • Promote alternative trans infrastructure	• Depending on mix of transportation choices and fuels, potentially fewer transportation-related GHG emissions and air pollutants.	• Diversity and redundancy in transportation can relieve pressure on transportation arteries, improve regional connectivity, and provide alternatives for escape in case of emergencies. • Transportation modes vary in their exposure and sensitivity to climatic extremes (e.g., heat, flooding, landslides, wildfire).	• Climate change-cognizant transportation planning must consider potential impacts from extreme events (floods, droughts, landslides, wildfire) to retain future reliability of the transportation system.
9. Strengthen and direct development toward existing communities • Develop centers that will function as hubs of economic activity	• Higher density, mixed use and accessible neighborhoods	• Fewer transportation-related GHG emissions and other air pollutants. • Development that includes energy efficiency, compact design and land use, and renewable energy reduces building and other energy consumption.	• High-density development can increase the urban heat island effect and thus increase exposure to extreme heat. • A diverse, stable, and vital economic base of communities enhances households' and government's adaptive capacity.	• Tree cover or green space can provide relief to the urban heat island effect. Many native trees require less water than imported tree species.
10. Take advantage of compact	• Higher density,	• Development that	• Compact building design	• Housing built with high levels

building design • Build up not out • Supports other modes of travel	mixed use and accessible neighborhoods	includes energy efficiency, compact design and land use, and renewable energy reduces building and other energy consumption.	tends to reduce energy use, thus lowers the financial burden on low(er) income households.	of insulation provides better protection from heat.
11. Enhance the economic vitality of the region • Promote economic development • Encourage high-tech industries • Foster a strong diversified economic base • Encourage economic activity • Develop a successful future economic strategy	• Establish a Green Job Initiative to promote local green job markets	• Depending on type of economic activity, economic growth can increase GHG emissions.	• A diverse, stable, and vital economic base of communities enhances households' and government's adaptive capacity. • Lower unemployment and poverty rates improve adaptive capacity and reduce the need for public services.	• Incentives for location of "green" technology attracts high-wage labor. • Priority placement of low-carbon-footprint industry and enterprises can foster overall sustainability goals.
12. Support actions that encourage environmental resource management • Understand the resource environment • Support a well-informed and active public • Preserve natural resources and enhance environmental protection • Manage the natural environment • Reduce environmental impacts of growth and development • Enhance recreation	• Climate registry • Renovation and new building of green buildings • Investigate feasibility of community choice energy aggregation • Set thermostats at 78°F or above in summer and 68°F and below in winter in city buildings • Passive solar designs for new buildings • Promote programs	• A transparent system of carbon accounting (registry) tends to enhance competition for low-carbon activities, processes, and products. • Overall GHG emissions reductions from energy use in buildings, in transportation, and public infrastructure.	• Improved awareness of risks from extreme heat and air pollution can help reduce people's exposure to these risks. • Improved awareness of actions people can take to protect themselves from heat extremes and air pollution can enhance their adaptive capacity. • Access to cooling spaces reduces exposure and enhances adaptive capacity. • Efforts to reduce air	• Experience with heat-health warning systems in other cities and regions suggests that "buddy" systems (people checking in and helping other people), agreements with power companies and active involvement of caregivers and health professional are important complements to information campaigns, educational outreach, and provision of cooling spaces.

opportunities in natural areas • Address clean air and climate change	for solar conversion at city buildings • Rebates for energy efficient appliances for mid to low income • Solar power street lights instead of conventional • Use of energy-efficient equipment and appliances • Integrated building design • Reduce standby losses • Distributed power generation for buildings • All transportation-related strategies above reduce GHG emissions • Prepare "one atmosphere" integrated air quality plan • Reduce CO • Public campaign about heat precautions/ measures for children, caregivers • Campaign to educate caregivers of vulnerable	pollution reduces exposure to pulmonary risks (which higher temperatures can make worse). • Active natural resource management can assist species adaptation. • A well-informed, actively engaged public has a higher adaptive capacity.	

	populations • Access to air conditioned cooling		
13. Plan For Future Water Needs • Promote water sustainability • Promote water conservation • Manage water supply and demand • Protect the aquatic environment • Manage variations in water supply • Provide adequate resource management	• (All strategies aimed at reducing energy use have indirect benefits for water resources, as water is required for most energy production.)	• Reduced pumping of groundwater reduces energy use. • Increased groundwater recharge increases energy use.	• Water management that is cognizant of projections of future demand and supply is better prepared for future changes. • Improved water resource accounting (measurement of groundwater and surface water supplies and use) allows for better planning. • Reduction of water use/water waste reduces the sensitivity to future water shortages. • Active groundwater recharge can reduce sensitivity to future water shortages.

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